5-2018

Assessing Variation in Air Quality Perception: A Case Study in Utah

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ASSESSING VARIATION IN AIR QUALITY PERCEPTION:

A CASE STUDY IN UTAH

by

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March 6, 2018

A capstone report submitted in partial

fulfillment of the requirements for the degree

of

MASTER OF NATURAL RESOURCES

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Logan, Utah

2018

ABSTRACT

In recent years, Utah has experienced poor air quality due to pollution-trapping winter inversions and summer ozone pollution. The resulting impacts of poor air quality include health issues, reduced visibility, economic impacts and ecological impacts. Utah's topography and exploding urban population are factors which increase human exposure to these adverse impacts of air pollution. It is important for State and local governments to understand how people perceive air quality so that clean air campaigns target those who are most likely to foster pro-environmental behaviors. An analysis was conducted using data from a state-wide survey conducted in July 2017. The survey focused on the public perception of climate change and air pollution. This study focused specifically on how people perceived the worst air quality day in their local area within the last year. Responses were compared to measured air quality data at respondents' nearest monitoring station. Data was mapped using Geographic Information Systems (GIS) and a regression analysis was also conducted to understand how socioeconomic factors played a role in air quality perception. The analysis found that residents of Salt Lake and Davis Counties reported experiencing the worst local air quality, followed closely by Weber and Utah Counties. Gender, political party, education and income were socioeconomic factors that influenced perceptions of poor air quality.

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CHAPTER 1 INTRODUCTION

1.1 Problem Statement

The quality of the air we breathe is important on a local scale because it affects how we live and is critical for our health. The effects of poor air quality can have social, economic and ecological impacts. Diminished well-being, increased health-care costs and loss of workdays are all attributed to breathing polluted air (Ainsaar et al., 2015; Heo, J. et al, 2016; Hausman et al., 1984). Air quality in Utah has become a major topic of concern for the public and local policy makers in recent years. During Utah winters, regional high-pressure and snow-covered valley floors contribute to temperature inversions (Wang et al., 2015) where pollution is trapped close to the valley surface by a warm air layer higher in the atmosphere. Utah's populated valleys are surrounded by mountains that act like a bowl, blocking airflow and contributing to stagnant, polluted air. During Utah summers, invisible ground level ozone poses serious health risks (Utah DEQ, 2016; Utah Department of Health, 2018). Ozone levels rise when human-generated chemicals react to sunlight creating unhealthy air conditions. These air quality phenomena have led to growing attention in the media and throughout the healthcare system, generating questions about the effectiveness of air quality regulation at the Federal and State levels (Penrod, 2018).

Regulation is a vital tool for industry, businesses and individuals to help improve the quality of the environment. Bryce Bird, Director of the Utah Division of Air Quality (DAQ) has stated that the division has focused on getting reductions in industrial air pollution, but it isn't enough (2017). The Utah DAQ has conducted sensitivity analysis showing that if all industrial emissions were eliminated, Utah still could not meet attainment standards because transportation and area sources constitute most of the emissions (Bird, 2017; Utah DAQ, 2016). Therefore, individuals may need to start changing their personal behaviors to have an impact on air pollution. An understanding of how people perceive air quality at a local scale is essential for those developing local air quality regulations (i.e., cities, counties, and regional government) and incentives to help individuals change their behavior. Lay people form perceptions of environmental risks that affect their responses to the risks; such risk perceptions provide important contextual information that expert studies may lack (Slovic, 1987). This research aims to identify factors influencing air quality perception in Utah by looking at the following: 1) spatial variation of perception; 2) how people perceive air quality in relation to measured data; and 3) if socioeconomic variables influence people's air quality perception.

The joint insights of the public and experts provide valuable contributions to improving air quality regulation. Identifying where the public perceive the highest risk will help local policymakers target populations that are more likely to practice pro-environmental behaviors. This could happen by tailoring policies, regulations, media campaigns and advertising to groups that perceive air quality as a threat and where measured data exhibit hazardous conditions. In conjunction with this, education programs can be adapted for local area concerns, rather than on a statewide scale. Once this has been successful, government leaders can then target those populations that are more skeptical about air quality problems. Improvements to air quality at the local scale will in turn have a bearing on the state's overall health.

1.2 Background Information

Air Pollution in Utah

Air pollution is any gas or particulate matter that is added to the atmosphere by natural or human-made activities, having adverse impacts to humans and the environment (Centers for Disease Control and Prevention, 2018; Marquit, 2008). Natural sources of air pollution include dust, smoke from wildfires, volcanic activity and biological processes in nature. Human-caused pollutants are generated from mobile, area and point sources. Mobile sources are primarily cars, trucks and airplanes. Area sources originate from home heating, agricultural burning, harvesting, construction, and wildfires. Point sources include power plants, refineries, and manufacturing facilities.

During Utah winters, atmospheric conditions typically exhibit a layer of cool air above a layer of warm air (temperatures decreasing with altitude) that mix and distribute pollutants between layers. However, after snowstorms these air layers are reversed or 'inverted' (temperatures increasing with altitude) when snow reflects, rather than absorbs heat from the sun. Warm air above acts like a lid, trapping unhealthy pollutants in the cold air layer close to the valley floor (Salt Lake City, 2017). High mountains that surround the Wasatch Front exacerbate the problem when cold air flows from mountain peaks into the valleys. Regional topography creates a barrier preventing unhealthy air from dispersing out of the valleys, as shown in Photo 1. Pollutants generated by various sources become trapped and produce unhealthy air conditions. Particulate matter (PM) is the pollutant of major concern during inversions. PM is a mixture of solid particles and liquid droplets found in the air (U.S. EPA, 2017a). PM can be categorized as either PM_{10} or $PM_{2.5}$. PM_{10} includes dust, pollen or mold particles that can be seen with the naked eye and are less than 10 micrometers in diameter. $PM_{2.5}$ includes fine inhalable particles such as organic compounds and metals that are less than 2.5 micrometers in diameter. Inhaling PM_{10} and $PM_{2.5}$ is hazardous because it can get deep into the lungs and bloodstream (U.S. EPA, 2017a).

During Utah's summers, air is hot and still. Vehicle emissions and industrial facilities creating nitrogen oxide (NO_2) and volatile organic compounds (VOC's) react with sunlight to create ground-level ozone (Utah DEQ, 2016). This type of ozone is not visible but can create hazardous health conditions, particularly during the early afternoon and evening hours. People are often unaware of ozone's hazardous levels because it is an invisible pollutant and they are less likely to perceive a problem (Nickerson, 2003).

Particulate pollution during inversions and ground-level ozone both result in detrimental impacts to people's health, visibility, and the State's economy and ecology. Beard et al. (2012), identified increased rates of asthma related emergency department visits during inversion days throughout Salt Lake County, Utah from 2003 - 2008. In addition, there is scientific evidence that breathing polluted air can lead to loss of intelligence, attention deficit disorders, heart disease, increased rates of autism, cancer and increased infant mortality rates (Pope et al., 2009 & 2013; Mustafić et al., 2012).

Photo 1 - Utah Inversion
Source: http://www.cleanair.utah.gov/winter/ inversions.htm

Haze degrades visibility in Utah's urbanized valleys in winter and also affects more remote areas of the State. Haze is caused when sunlight hits tiny pollution particles in the air, which reduces the clarity and color of what we see (U.S. EPA, 2017b). Utah Governor Gary Herbert has expressed concern that poor visibility dampens Utah's tourism industry and deters businesses from locating in Utah (Herbert, 2017). Degraded visibility has become a problem in many of the State's national parks, particularly Canyonlands National Park (U.S. EPA, 2016a). Utah's national parks rely on scenic resources to attract tourist revenue; therefore, haze may have negative impacts on visitor spending.

Poor air quality can have big impacts to Utah's economy. Small amounts of pollution have been shown to reduce worker productivity by just over four percent (Zivin et al., 2012). Hausman et al. (1984) explain that an increase in suspended particulate matter also contributes to a ten percent increase in work days lost, impacting the employee, businesses and the economy as a whole. It is the EPA's opinion that clean air and a healthy economy go hand in hand. The agency states that "Economic welfare and economic growth rates are improved because cleaner air means fewer air-pollution-related illnesses, which in turn means less money spent on medical treatments and lower absenteeism among American workers" (U.S. EPA, 2011).

Air quality is also an important component of Utah's ecosystems. The combination of the chemical components of pollutants, weather conditions and sensitivity of resources can directly and indirectly lead to environmental degradation (National Park Service, 2017). Vegetation can become discolored and stunted by ozone. Streams become acidified, negatively affecting aquatic species habitat and health. Increased inputs of fixed nitrogen to natural waters can significantly contribute to eutrophication problems. Soil nutrient availability is decreased and rock formations eroded as a result of acid deposition (National Park Service, 2017). In urban settings, building surfaces become eroded and discolored because of acid rain and particulate matter buildup.

The resulting impacts of poor air quality: health issues, reduced visibility, economic impacts and ecological impacts, all contribute to perceptions of air quality by individuals. They are an important component of air quality perception.

How is Air Quality Measured?

Air quality is typically measured and reported using an Air Quality Index (AQI). The index tells people how clean the air is on any given day, focusing on health impacts after a few hours of breathing the air. The AQI is calculated for four of the air pollutants regulated by the Clean Air Act (1970): ground level ozone, particle pollution, carbon monoxide, and sulfur dioxide (U.S. EPA, 2014). Each of these pollutants has an established national threshold to protect people's health. AQI values range from 0 to 500. According to the EPA, when the AQI exceeds 100, it exceeds the threshold established by the EPA for healthy air and may adversely affect sensitive groups such as children and those with respiratory conditions. An AQI value of 300 would have serious health effects for everyone exposed (U.S. EPA, 2014). Table 1 shows the AQI thresholds established by the EPA.

Various public and private agencies including the Utah Department of Environmental Quality, The Utah Division of Air Quality, Utah Department of Health, AirNow.gov and Intermountain Healthcare use the AQI to provide timely information to the Utah public through media.

Air Quality Thresholds Established by the EPA		
Air Quality Index Value	***Levels of Health Concern***	***Colors***
When the AQI is in this range...	*... air quality conditions are:*	*... as symbolized by this color*
0 to 50	Good	Green
51-100	Moderate	Yellow
101 - 150	Unhealthy for Sensitive Groups	Orange
151 - 200	Unhealthy	Red
201 - 300	Very Unhealthy	Purple
301 - 500	Hazardous	Maroon

Table 1 – Air Quality Thresholds Established by the EPA

How is Air Quality Monitored?

The EPA uses outdoor monitoring stations throughout the United States to document ambient pollutant levels for NO_2, Ozone, $PM_{2.5}$, PM_{10} and VOC's. Under the EPA's guidance, State, local and tribal government develop and operate these networks. The monitoring stations that the EPA utilizes in Utah are shown in Figure 1. Most of the monitoring stations that the EPA uses in Utah are operated by the Utah Division of Air Quality (DAQ). The DAQ operates a 21-station monitoring network throughout the State. Half of DAQ's monitoring stations collect pollutant data, the other half collect only meteorological data. According to the Utah Department of Environmental Quality (DEQ), the stations are located to be, "representative of local and regional pollution levels" (Utah DEQ, 2017). The information collected from these monitoring stations are used to calculate air quality, health advisories, winter wood burning conditions and summer season action day alerts. Data from these stations are compared to National Ambient Air Quality Standards, which policymakers then use to develop pollution reduction strategies (Utah DEQ, 2017).

1.3 Air Quality Laws and Regulations

The Clean Air Act

The Clean Air Act is a Federal law that was enacted in 1970. The Act gives the EPA the authority to establish National Ambient Air Quality standards (NAAQ's) for the nation and limit hazardous pollutant emissions. The original goal of the Act was for each State to attain the NAAQ's by 1975 and to have each state form a State Implementation Plan (SIP) to control industrial pollutants (EPA, 2017c). Many areas of the country, including Utah, did not meet the NAAQ's by the 1975 deadline, therefore amendments were made to the Act in 1977 and 1990 to adjust goal deadlines (EPA, 2017c). The 1990 amendment required technology-based standards for "major sources" in each state. According to the EPA, "Major sources are defined as a stationary source or group of stationary sources that emit or have the potential to emit 10 tons per year or more of a hazardous air pollutant or 25 tons per year or more of a combination of hazardous air pollutants" (2017c). The EPA monitors major pollution source data every eight years to assess if risk is occurring and/or if standards need to be revised for these sources. Violations of the Clean Air Act can result in fines and/or up to 15 years in prison if convicted pursuant to 18 U.S.C. 357. In the event of a second offense, penalties may be doubled (Statute: 42 U.S.C. 7413(1)).

Utah State Implementation Plan

The process of amending and revising SIP's has become an iterative process as air quality regulations have evolved over the years. According to the Utah DAQ, Utah submitted a SIP to the EPA in January 1972 which was revised by the EPA in areas where it was lacking (2017a). The State was successful in reducing pollutants up until the required attainment dates, but not sufficiently to meet the NAAQS. The Utah DAQ (2017a) indicates that no reduction was noted for particulate matter. As explained previously, the Congress recognized that many States were not achieving successful pollutant reductions, therefore they required each state to identify

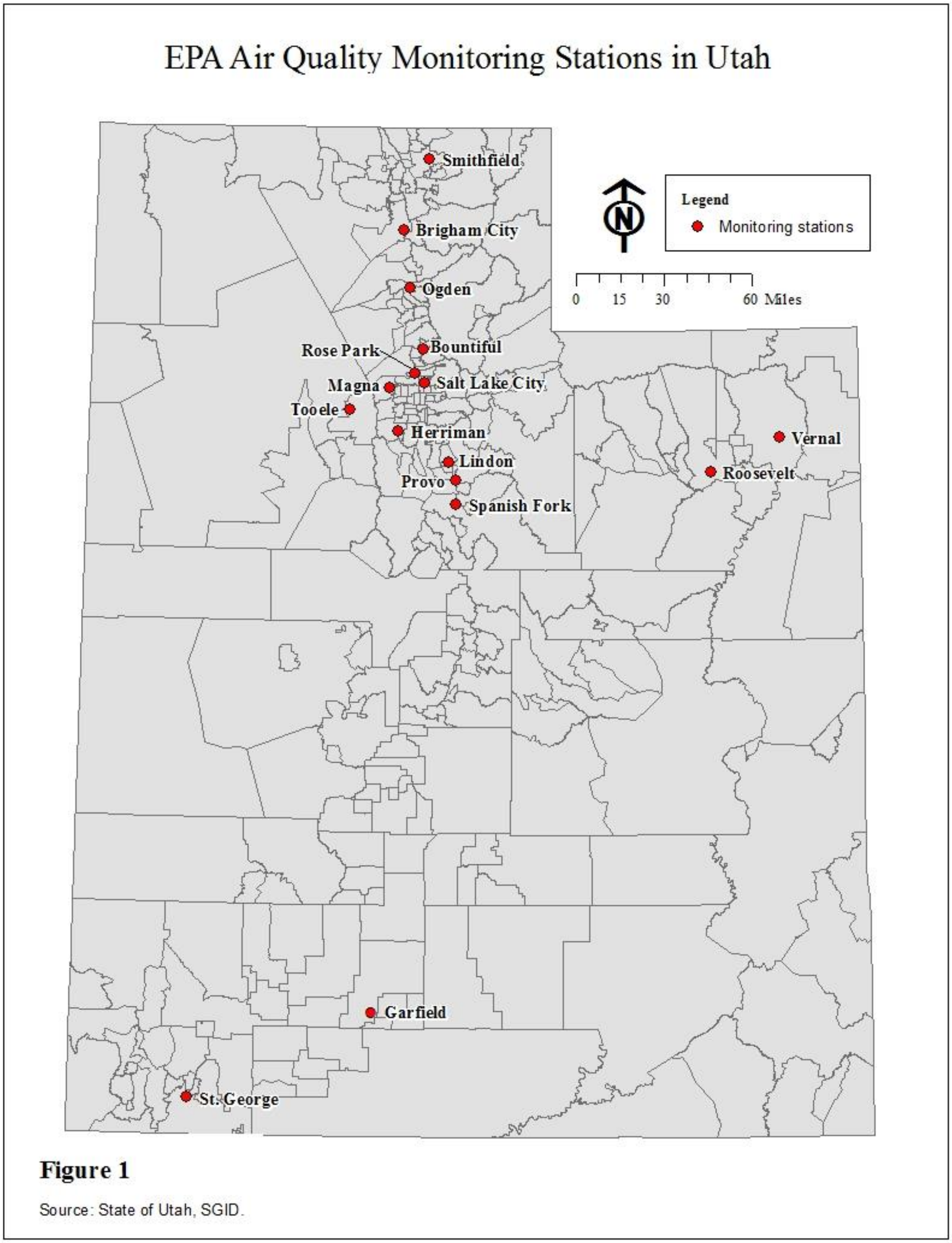

Figure 1 - EPA Air Quality Monitoring Stations in Utah

non-attainment areas that exhibited high pollutant levels from measured data. The Utah SIP was revised to reach NAAQS by December 1982 for particulate matter and carbon monoxide (DAQ, 2017a). The State was also required to adopt technology to control hydrocarbon releases to meet ozone standards (DAQ, 2017a). Air quality monitoring data, emissions inventories, meteorology and topography were used to determine that Salt Lake, Davis and Utah Counties did not meet attainment standards (DAQ, 2017a).

A further revision to the SIP occurred to extend the attainment deadline to 1987 and Utah committed to inspect motor vehicles and require that maintenance occur on those vehicles that did not meet minimum requirements (DAQ, 2017a). Lawsuits between citizens groups and the EPA followed during the 1990's and further revisions to the PM_{10} requirements were mandated by the EPA. Utah County and Salt Lake County met PM_{10} attainment standards from 1993 to 2003 (DEQ, 2006).

In 2006, 24-hour $PM_{2.5}$ attainment standards were reduced from 65µg/m^3 to 35µg/m^3 (DAQ, 2017b). In 2009, the EPA determined that Davis, Salt Lake and Utah County were unable to meet these revised 24-hour $PM_{2.5}$ standards and as a result, Utah's Moderate Area SIP's were developed.

In 2009, the EPA designated three areas of the State as nonattainment areas for the 2006 24-hour $PM_{2.5}$ standard, including Logan, Salt Lake City and Provo. In 2013 the State was required by a D.C. Circuit Court of Appeals ruling to publish a new SIP for $PM_{2.5}$ non-attainment areas and reclassified them as Moderate Areas. According to Utah DAQ, "Utah resubmitted its three $PM_{2.5}$ plans and was required to demonstrate that each area would either attain the standard by December 31, 2015, or that it would be impracticable to do so even after applying all reasonable control measures" (Utah DAQ, 2017c).

In May 2017, the EPA reclassified the Salt Lake City and Provo non-attainment areas from Moderate to Serious for the 2006 24-hour $PM_{2.5}$ NAAQS (Utah DAQ, 2017d). New Serious Area SIP's were developed in 2017 and required that NAAQS demonstrate attainment by the end of 2019 (Utah DAQ, 2017d). If the State doesn't meet this deadline, it can apply for a five-year extension with the caveat that more stringent measures are implemented in these areas (Utah DAQ, 2017d). In addition to the Moderate Area SIP requirements, Serious Area SIP's incorporate: a) updated emission inventories including a base year (2014) and an attainment year; b) evaluation and adoption of control measures for direct $PM_{2.5}$; c) application of Best Available Control Technology to attain pollutant limits; d) an attainment demonstration date (initially 2019); and resubmission of Serious Area SIPs if attainment fails (Utah DAQ, 2017d).

1.4 Goals and Objectives

This capstone focused on the influence that local setting (proximity and place) and socioeconomic factors have in forming air quality perceptions in Utah. I sought to improve knowledge about public perceptions of air quality in Utah by linking spatial information with primary survey data on public perceptions. As explained above, Utah has accurate and widespread air quality data throughout the state that is accessible through the EPA website. We might expect that there would be a strong correlation between measured air pollution and greater awareness of environmental risk, particularly in urban areas (Elliott et al., 1999). However, Dworkin and Pijawka (1982) found that the people in Toronto, Canada, were insensitive to changes in their local air quality when they were surveyed. Brody et al. (2004), explained that the disconnect that Dworkin and Pijawka found may have been attributed to what is known as a "halo effect," where "...individuals are reluctant to attribute high levels of air pollution to their neighborhood or home area." It was my goal to see if there is correlation between Utahns' location and perceived air quality, or if a "halo effect" is occurring. I did this by using Geographic Information Systems (GIS) to map perceptions throughout the state. I then conducted a regression analysis to understand the influence of multiple factors together (Section V. Methods for description of spatial and quantitative analysis). If there is a strong relationship between perceptions and measured air quality, then feedbacks between perceptions and behavior could be facilitated by policymakers and other communicators. In other words, people could be encouraged to respond to the poor air quality they experience by changing their behavior. However, if there is less of a relationship between measured air quality and perceptions, then communicators may need to first understand what factors are influencing perceptions to develop appropriate behavior-change messages. Those with strong negative attitudes towards air quality may be harder to coerce into pro-environmental behaviors. This analysis aimed to identify places where perceptions differed from measured data, providing guidance for targeting communication campaigns geographically.

Utahns' air quality perceptions may not only be a function of measured air pollution or geographic location. Social and cultural experiences may play an important role in how people perceive air quality. Variables such as gender, age, education, income, race and longevity in an area may influence air quality perception. Lai and Tao (2003) conducted research on environmental threat levels for people in Hong Kong, China. Their results indicated that women, older people, and less educated individuals are more likely to consider environmental hazards as threatening compared to men who are younger and have more education. In contrast, Howel et al. (2002) conducted a study in north-east England on the role that place has on air quality perception. When they looked at gender, they consistently found little or no difference between perceptions. However, they did find that older people tended to rate local air quality as poor. They attributed this to older people having memories of bad air pollution in the past (Howell et al., 2002). Tiefenbacher and Hagelman (1999) conducted a study in Texas that suggested income is positively correlated with proximity to sources of air pollutants. In the same study, the authors found that counties in Texas with higher percentages of minority populations had higher pollution emissions. In another study in Texas, Chakraborty et al. (2001) found that personal perception of air quality health risks was significantly higher for non-Hispanic Black and Hispanic residents, compared to non-Hispanic Whites. Some research indicates that the degree of perceived air pollution is associated with lower household incomes and deprived economic communities are more likely to perceive poor air quality (Kim et. al (2012), Bickerstaff and Walker (2001)). There is very little scientific information on the role that religious affiliation plays on air quality perception. This study aimed to see if religion was a significant factor in how respondents perceived air quality. I planned to see if, aside from measured pollution levels and geography, these socioeconomic variables play a role in forming perception. I did this by comparing socioeconomic indicators to air quality perception.

As explained previously, the AQI is an essential tool that the public can use to assess air quality risks and take measures to protect their health. The EPA requires that metropolitan areas with populations of 350,000 or greater are required to report the AQI at least five days per week to the public (U.S. EPA, 2016b). The EPA encourages local agencies to provide this information in as many ways as possible to the public, including television, newspaper, radio, phone, web pages and social media.

Given that agencies are required to report AQI information in urban areas, I anticipated that perceptions of air quality in urban areas would be more accurate than in rural areas because access to AQI may play a role in how perception is formed. I did not think that gender would influence perception, nor did I anticipate that religious or political affiliation would have a bearing on perception like it may with an issue such as climate change that has become strongly politically polarized. The research indicates that respondents with less education are more likely to perceive air pollution as a threat than higher-income groups and I anticipated that they would be more aware of poor local air quality. Similarly, I thought that lower-income respondents may be more aware of air pollution because they tend to live in areas closer to industry and point source pollutants.

CHAPTER 2 METHODS

2.1 Surveying Air Quality Perception

This study uses data from a survey of Utah residents conducted by Drs. Layne Coppock and Peter Howe at Utah State University, supported by the Utah Agricultural Experiment Station. Qualtrics, a national survey company based in Provo, Utah, was contracted by Utah State University to administer the survey in July 2017. Human subjects Institutional Review Board approval was obtained from Utah State University. The survey asked the public about their perceptions of climate change and air quality as well as demographic information (age, gender, race, education level, zip code, and political and religious affiliation). Respondents completed the survey between July 20, 2017 and July 26, 2017. Qualtrics used a quota sample of respondents from online panels across different geographic locations and demographics who had agreed to complete surveys. The panels mimicked a representative survey of the population of Utah and approximated a random sample. There were 1,508 total responses to the survey. The survey was completed entirely online, therefore there was a risk that some populations were under sampled, such as the elderly, low income populations or those in geographic areas without internet access. To address these sampling biases, results were weighted by age, gender, education and income to match their respective population proportions in the state. Additionally, although this was a statewide survey, we anticipated that 85-90% of the respondents would be from the Wasatch Front because that is the most densely populated region of the state. Figure 2 shows that as predicted, most survey respondents lived along the Wasatch Front in Weber, Davis, Salt Lake and Utah counties.

The Qualtrics survey asked multiple questions regarding air quality and climate change. For the purposes of this research, I focused on the following question regarding air quality perception:

Q 3.2 Consider the air quality in your local area and think about the one day during the past year when the air quality was the worst. How would you label the air quality on that day?

- *A. Good*
- *B. Moderate*
- *C. Unhealthy for sensitive groups*
- *D. Unhealthy*
- *E. Very Unhealthy*
- *F. Hazardous*

Answers to this question directly relate to the AQI categories provided by the EPA, as shown in Table 1. Prior to analyzing the survey responses to air quality perception, a spatial sensitivity analysis was conducted on zip code locations to measure the uncertainty of results (see Section 2.2, Spatial Analysis).

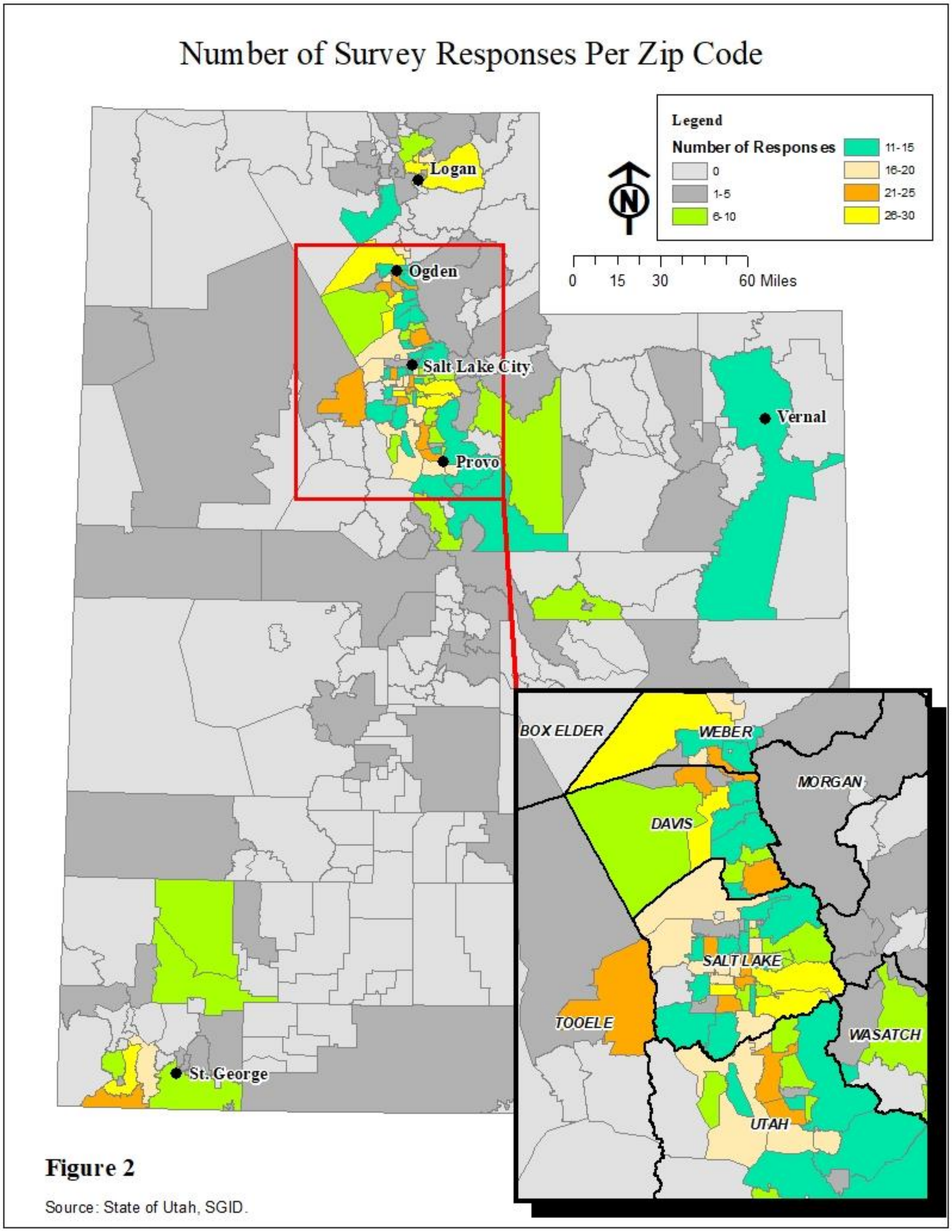

Figure 2 - Number of Survey Respondents Per Zip Code

2.2 Spatial Analysis

To compare perceived air quality to measured data, respondents needed to be assigned to their nearest air quality monitoring station. Zip codes were chosen as geographic boundaries to compare perception with measured air quality data because it helped develop more precise conclusions about perception than at a broader level (like county or region). Respondents only provided their zip codes (not physical addresses), therefore the centroid for each zip code was chosen as the geographic point from which linear measurements were taken to monitoring stations. As a result, there was slight variation in distances from a monitoring station, but responses would be from within the same zip code. Several survey respondents reported zip codes that were in Phoenix, Arizona and Las Vegas, Nevada, therefore they were removed from the dataset prior to spatial or statistical analysis. Respondents that did not answer survey question 3.2 (see Section 2.1, Surveying Air Quality Perception) were also removed prior to analysis.

Sensitivity Analysis

A sensitivity analysis in the distance bands used to associate measured air quality with responses was conducted to help develop more meaningful conclusions from the data given the geographic factors associated with perception. I began by using a 25-mile buffer, under the approximation that in northern Utah one can see approximately 25 miles in the distance from the foothills of the mountains on the Wasatch Front (where most respondents live). A 25-mile buffer was tested around each monitoring station to see which zip code centroids were captured (see Figure 3). In all, 156 zip code centroids, and 1,257 respondents were covered by the 25-mile buffer. As Figure 3 shows, there is substantial overlap along the Wasatch Front buffers and most of central and southwestern Utah are not covered at all.

To see if a larger buffer would capture more respondents, a 35-mile radius was tested (see Figure 4). The 35-mile buffer encompassed 191 zip code centroids and 1,278 respondents. This was only a 1.7 % increase from a 25-mile buffer, or an additional 21 respondents. This difference is primarily comprised of responses from Heber and Cedar City with 6 and 9 responses respectively, all other zip codes having two or less responses. Given that the larger 35-mile buffer creates redundancy, particularly along the Wasatch Front where most survey respondents live, the 25-mile buffer was used to improve accuracy of the study and eliminate responses that were too far from a monitoring station.

Data Quality

The Garfield monitoring station only had EPA data available between July 2016 and December 2016. Although this monitoring station encompassed 12 zip code centroids, no survey respondents were captured within the 25-mile buffer and only three were captured within the 35-mile buffer. Given the incomplete air quality data and very small number of responses, this monitoring station and associated responses were eliminated from the study. After the elimination of the Garfield monitoring station, 149 zip codes remained to be analyzed within the 25-mile buffer zones, covering 1,254 respondents. From this point onward, only zip codes that

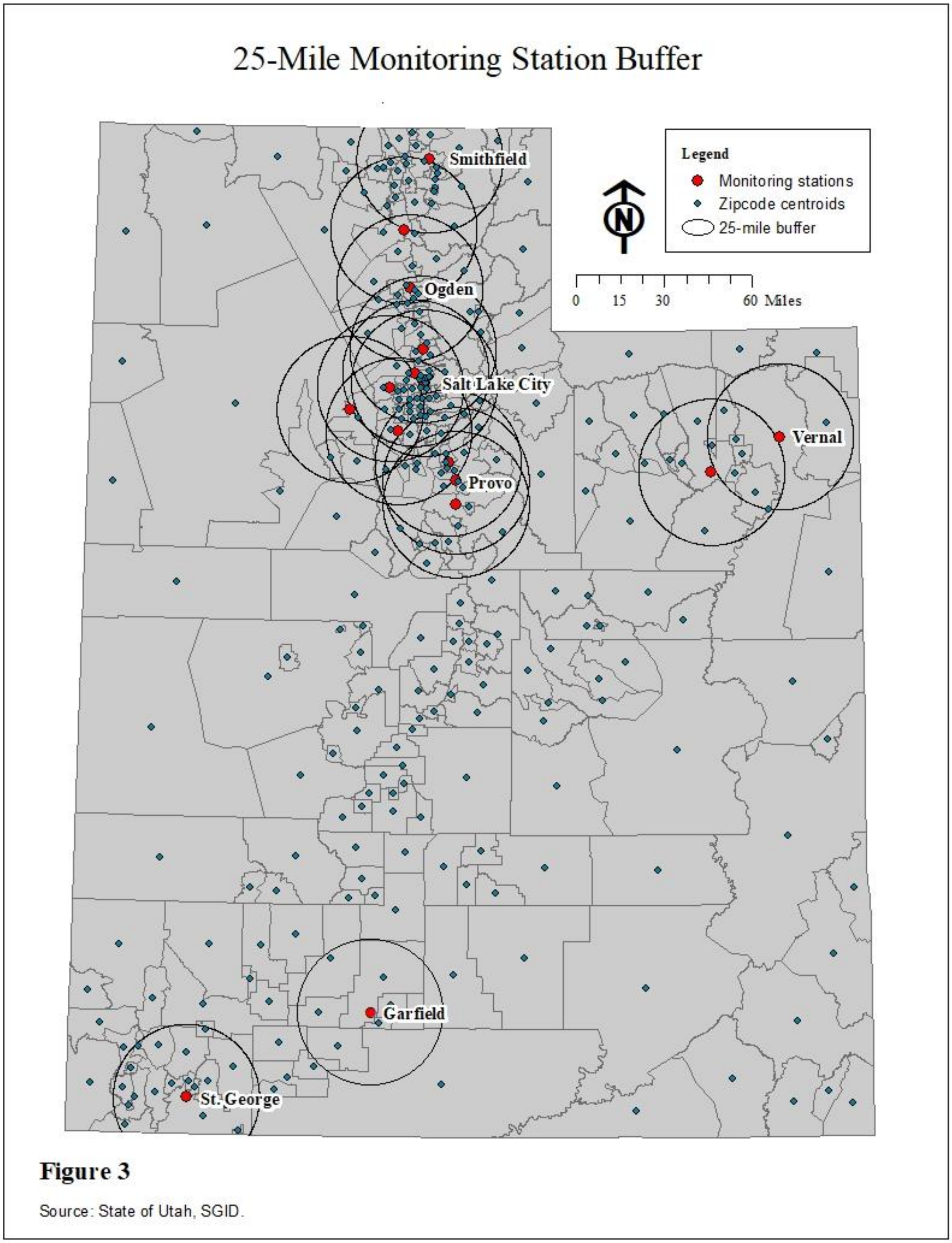

Figure 3 - 25-Mile Monitoring Station Buffer

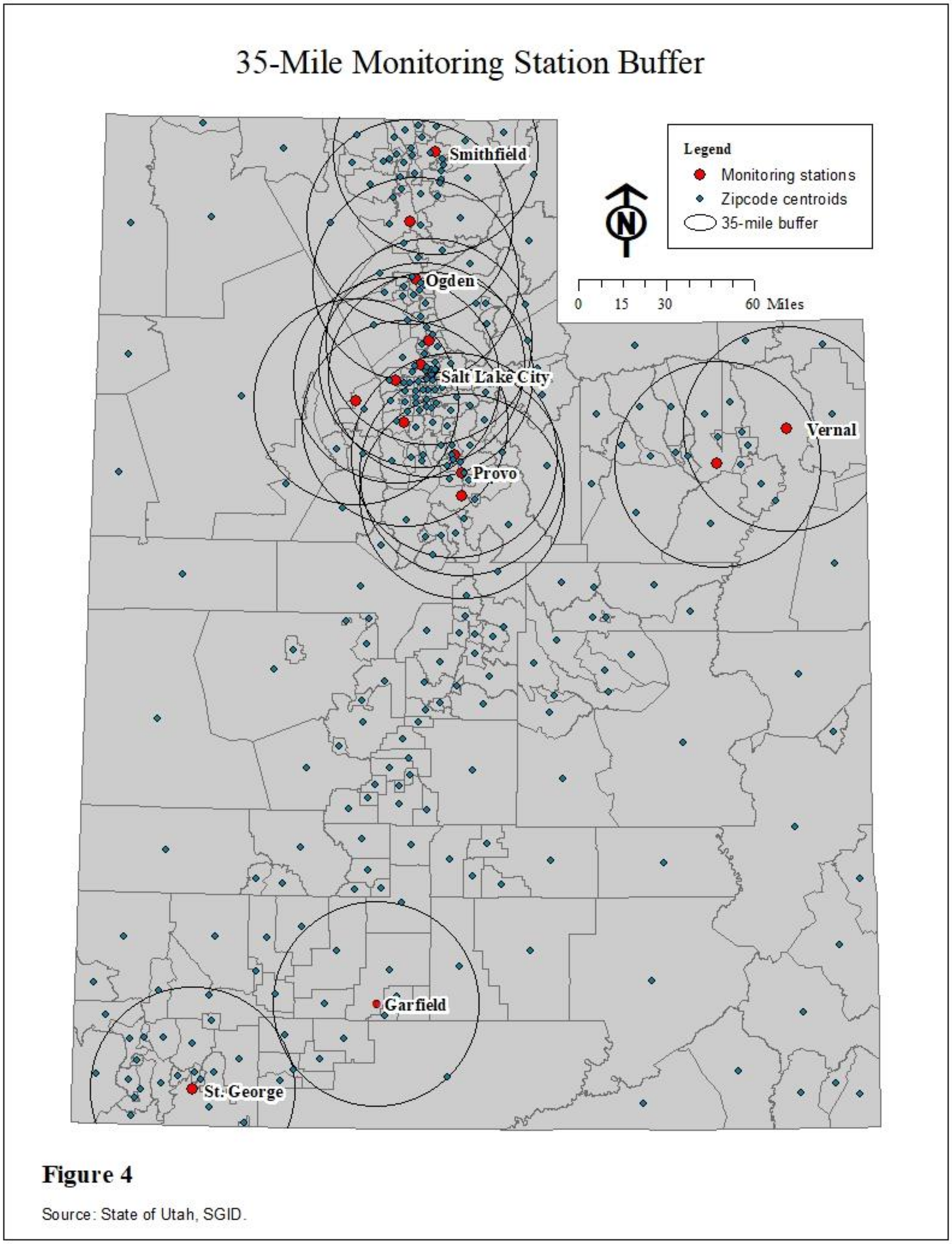

Figure 4 - 35-Mile Monitoring Station Buffer

were located within the 25-mile buffer of selected monitoring stations (all but Garfield) and that had responses to survey question 3.2 were considered in the spatial analysis.

Nearest Monitoring Stations

I used the ESRI ArcGIS "Near" tool to identify the nearest monitoring station to each zip code centroid. This function calculated the shortest distance as-the-crow flies between each centroid and monitoring station location. Figure 5 shows which zip codes are associated with which monitoring station.

There were problems associated with using the 'Near' method, in that it did not account for regional topography of the landscape. For example, Park City is located along the Wasatch Back (east of the Wasatch mountain range), and the nearest monitoring station is Salt Lake City. From Park City, mountains completely block the view of the Wasatch Front (west of the mountain range), where the nearest monitoring station is located. If there were another monitoring station on the east side of the mountains, I would have adjusted the function to co-locate Park City zip codes to that, but in this case, there was not. Air quality differs in these two locations, so air perception conclusions are not able to control for local measured air quality for zip codes along the Wasatch Back.

I encountered a similar problem with the Roosevelt and Vernal monitoring stations when using the 'Near' function. The zip code polygon for Vernal is shaped irregularly and as a result, the centroid was located on the western edge of the polygon. This resulted in the Vernal zip code (84078) being assigned to the Roosevelt monitoring station. I assumed that the people who responded from this zip code lived in the Vernal city limits or in very close proximity, therefore this zip code's nearest monitoring station was manually changed and assigned to the Vernal monitoring station to improve accuracy.

Despite the potential inaccuracies of using this method, I deemed it the simplest, most unbiased method to systematically provide locations for the majority of zip codes I was analyzing.

2.3 Measured Air Quality Data

The EPA produces a database (the AQS DataMart) that allows the public to view daily statistics for multiple pollutants at specific monitoring stations throughout the United States (EPA, 2017d). State, local and tribal agencies are required to submit air quality data to EPA every quarter, but most do so daily as data become available (EPA, 2017b). The EPA has a network of 16 monitoring stations in Utah that it received data from in 2016 and 2017. The network is more comprehensive than the Utah DAQ, therefore all AQI data was collected directly from the AQS Data Mart rather than from the Utah DAQ. This allowed for all data in this study to be consistent.

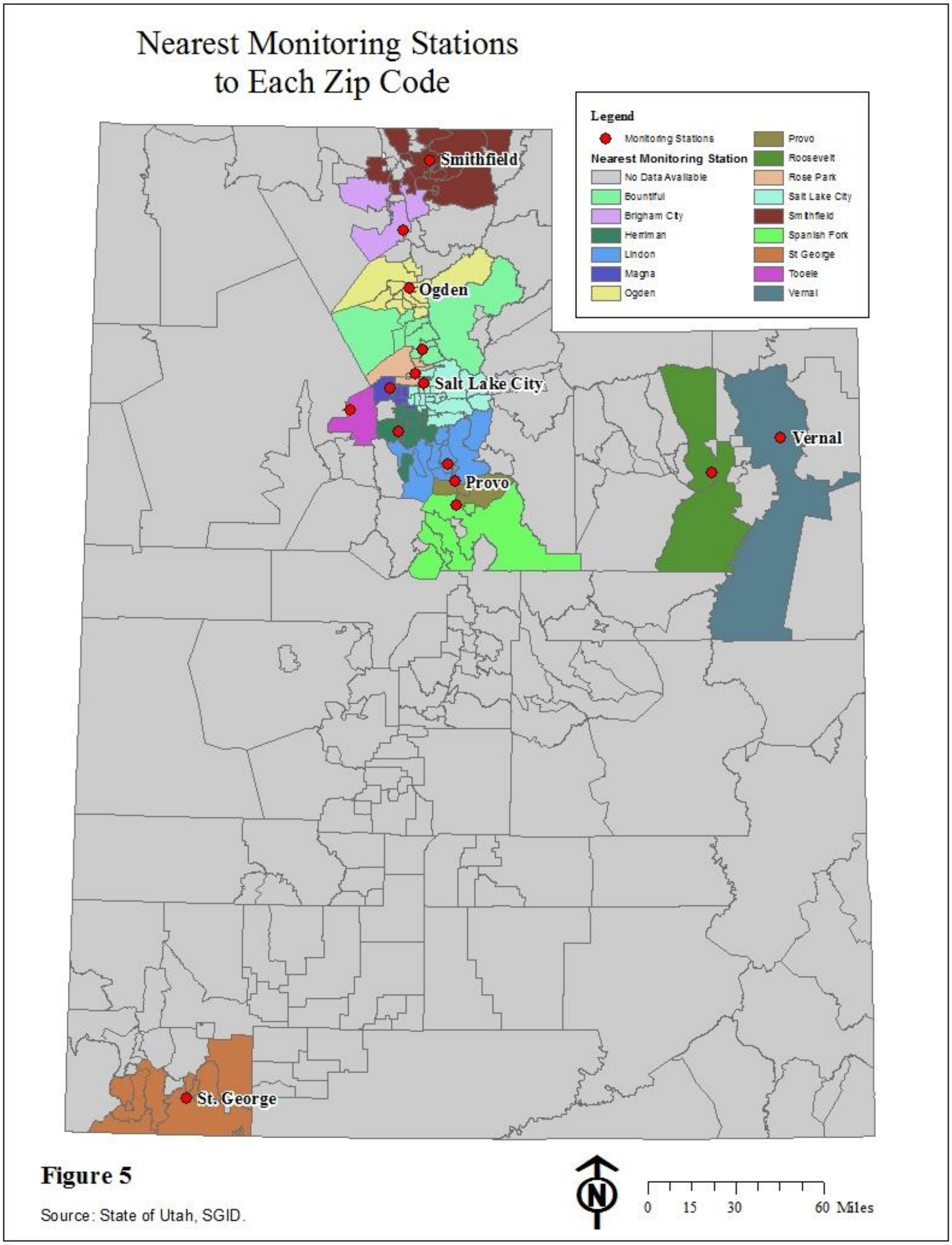

Figure 5 - Nearest Monitoring Stations to Each Zip Code

The database was used to select $PM_{2.5}$ as the focal criteria pollutant because AQI values utilize $PM_{2.5}$ levels as a benchmark. The calendar year, State and monitoring station are selected as criteria to obtain the data from the EPA's AQS DataMart.

Question 3.2 of Qualtrics survey asked respondents to reflect on the worst air quality day in their local area over the past year, as discussed in Section 2.1, Surveying Air Quality Perception. The survey began on July 20, 2017 and ended on July 26, 2017, therefore, I analyzed air quality data results between July 20, 2016 and July 26, 2017 at each of the Utah monitoring stations to cover the full year and the time that the survey was being conducted. Summarized results are shown in Table 2.

Table 2 shows that each monitoring station is assigned an EPA site identification number. I assigned a station code to each monitoring station consisting of the station's first two letters to keep the data organized and reduce error. The worst daily AQI value was found at each of the stations (U.S. EPA, 2017d) and categorized based on the EPA's AQI values shown in Table 1. The date of the worst AQI was also recorded. It should be noted that every monitoring station had a complete set of data throughout the year except for Garfield. The Garfield monitoring station only had data from 2016. As explained in Section 2.3, Spatial Analysis, this monitoring station was eliminated as a source of air quality information.

Worst AQI Designations at Each Utah Monitoring Station Between July 2016 and July 2017

EPA Site ID	*Station Name*	*Station Code*	*Max AQI*	*AQI Designation*	*Worst AQI Date*
490030003	Brigham City	BC	153	Unhealthy	2/2/2017
490050007	Smithfield	SM	167	Unhealthy	2/2/2017
490110004	Bountiful	BO	126	Unhealthy for Sensitive Groups	12/30/2016
490130002	Roosevelt	RO	114	Unhealthy for Sensitive Groups	2/4/2017
490170101	Garfield	GA	25	Good	7/26/2016
490351001	Magna	MA	104	Unhealthy for Sensitive Groups	1/31/2017
490353006	Salt Lake City	SL	151	Unhealthy	12/30/2016
490353010	Rose Park	RP	130	Unhealthy for Sensitive Groups	2/2/2017
490353013	Herriman	HE	128	Unhealthy for Sensitive Groups	1/31/2017
490450004	Tooele	TO	99	Moderate	10/15/2016
490471004	Vernal	VE	76	Moderate	1/31/2017
490490002	Provo	PR	154	Unhealthy	1/31/2017
490494001	Lindon	LI	155	Unhealthy	1/30/2017
490495010	Spanish Fork	SF	161	Unhealthy	2/1/2017
490530007	St George	SG	97	Moderate	6/25/2017
490570002	Ogden	OG	162	Unhealthy	7/4/2017

Table 2 - Worst AQI Designations at Each Utah Monitoring Station

The number of responses from each zip code varied between zero and 29. To make comparisons between zip code AQI perception and the measured AQI at each monitoring station, zip code responses were averaged and rounded to the nearest number (1 = 'Good', 2 = 'Moderate', 3 = 'Unhealthy for Sensitive Groups', 4 = 'Unhealthy', 5 = 'Very Unhealthy', and 6

= ‘Hazardous’). The average was used to reflect the severity of the responses. The mode was not used because several zip codes had only two responses making the mode difficult to calculate. Average perceived air quality by zip code is shown in Figure 6.

2.4 Comparing Air Quality Data

After each zip code had a monitoring station assigned, the worst AQI value at each monitoring station was also identified for each zip code. Figure 7 shows the worst measured AQI values at each of the co-located zip codes. Having the average perceived air quality and the measured air quality for each zip code allowed for a direct comparison to see any differences occurred.

Actual measured data was subtracted from the average perceived data for each zip code, resulting in an accuracy score. Figure 8 shows the difference between measured and perceived air quality. Positive numbers indicated that respondents overestimated pollution. The higher the number, the less accurate their perception was. A score of zero indicated that respondents perceived air quality accurately – there was no difference between their perception and the measured air quality data. Negative scores indicated that respondents underestimated pollution levels in their local area. The lower the number, the less accurate perception was. Perceived, measured, and accuracy score data for each analyzed zip code can be found in Appendix A.

2.5 Quantitative Analysis

As discussed in Section 1.4, Goals and Objectives, scientific literature indicates that socioeconomic factors may influence air quality perception. Several questions were asked that could be answered by conducting a quantitative analysis on the survey data. For this study the questions I aimed to answer were as follows:

Questions to Answer

1. How well do the measures of gender, age, education, political affiliation, religion, county location, and income predict the accuracy of air quality perception?
2. How much variance can be explained by a multiple linear regression model that includes geographic and socioeconomic predictors?
3. Which is the best predictor of perceived air quality: measured data, gender, age, education, political affiliation, religion, county location, or income?

Descriptive statistics were used to describe the demographics of survey respondents. Responses that did not provide age were removed from the analysis. Race or ethnicity was not included in the statistical analysis, because as described in Section 3.1, General Survey Results, an overwhelming majority of respondents identified themselves as white or Caucasian. Meaningful relationships would therefore be hard to determine because of limited racial/ethnic variation.

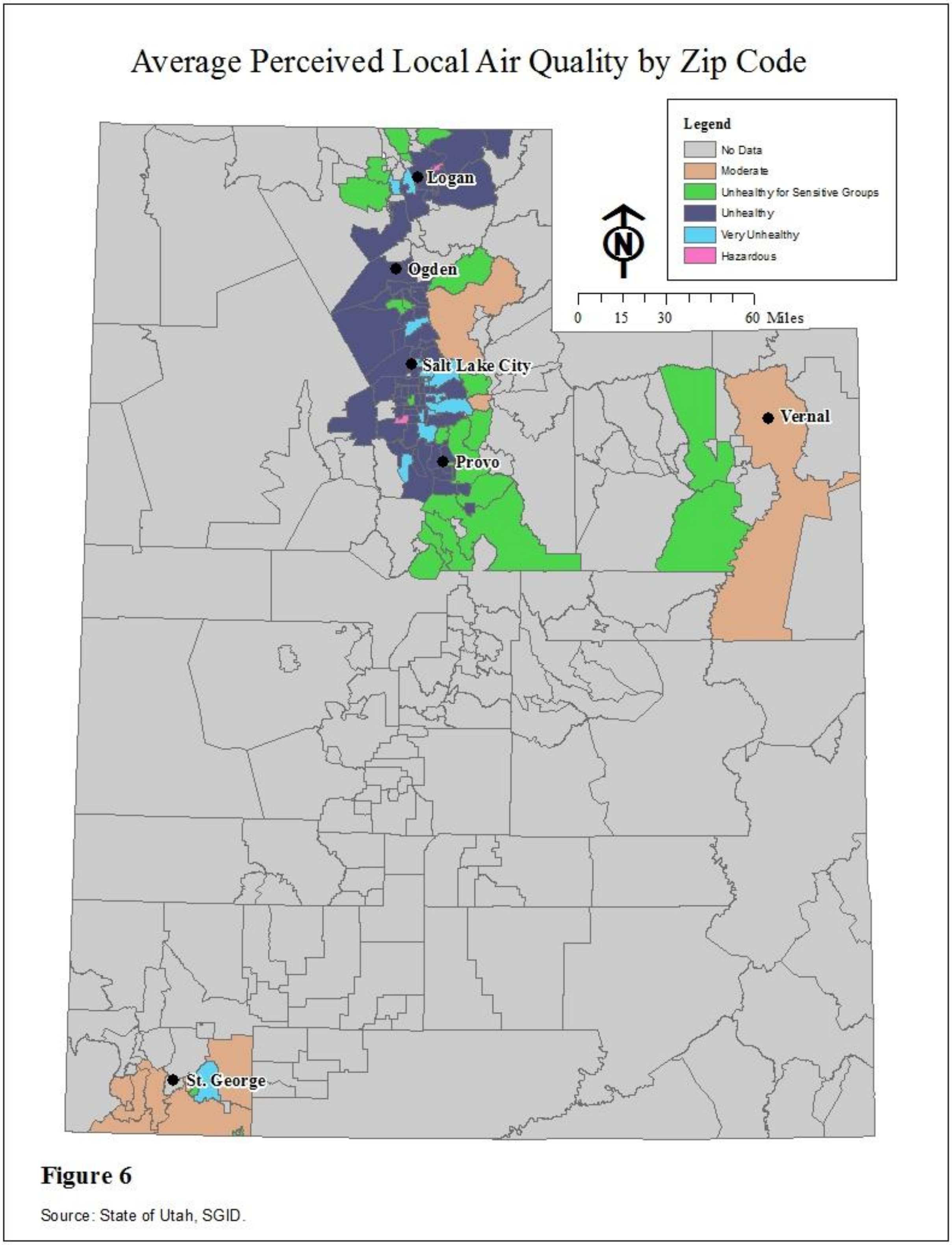

Figure 6 - Average Perceived Local Air Quality by Zip Code

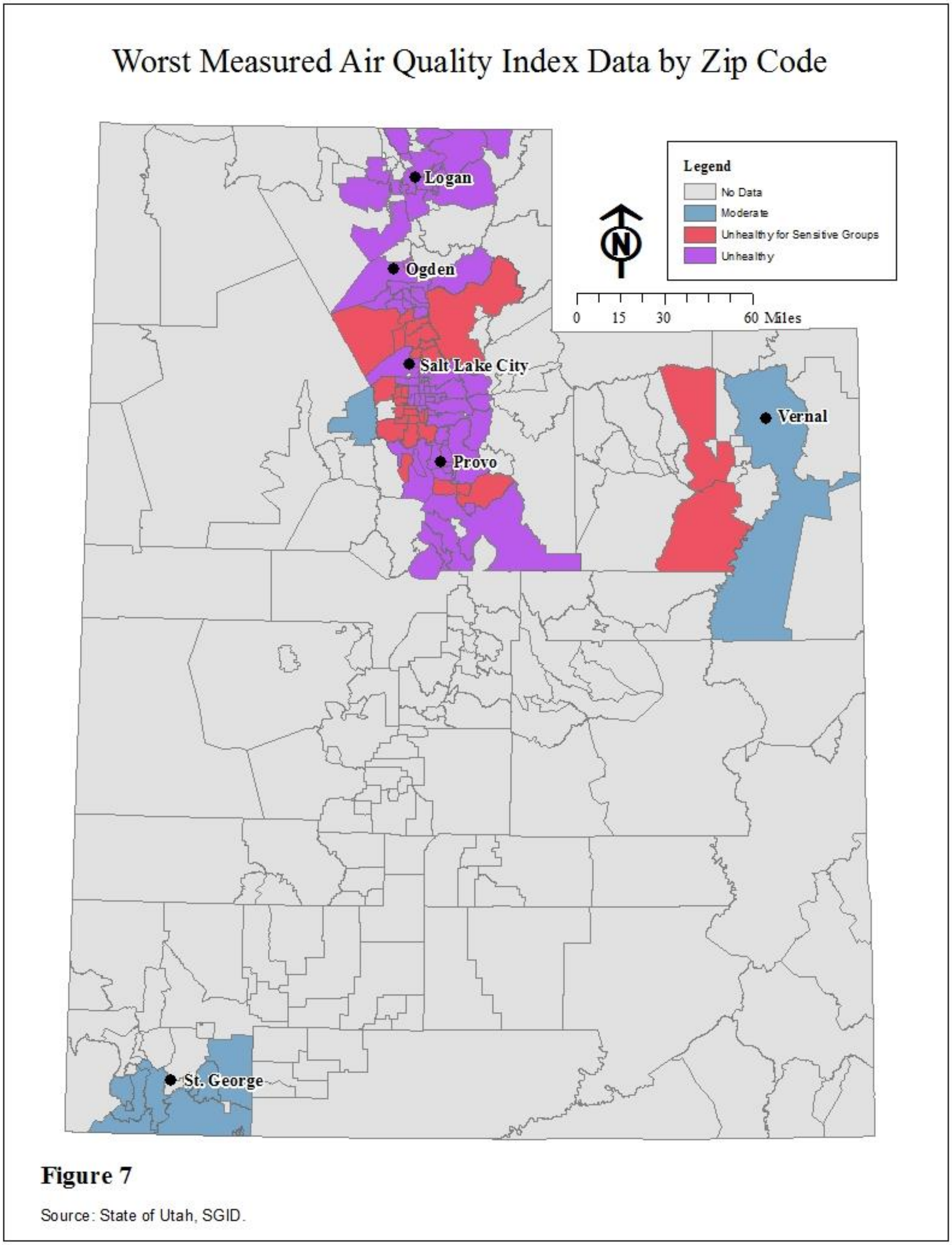

Figure 7 - Worst Measured Air Quality Index Data by Zip Code

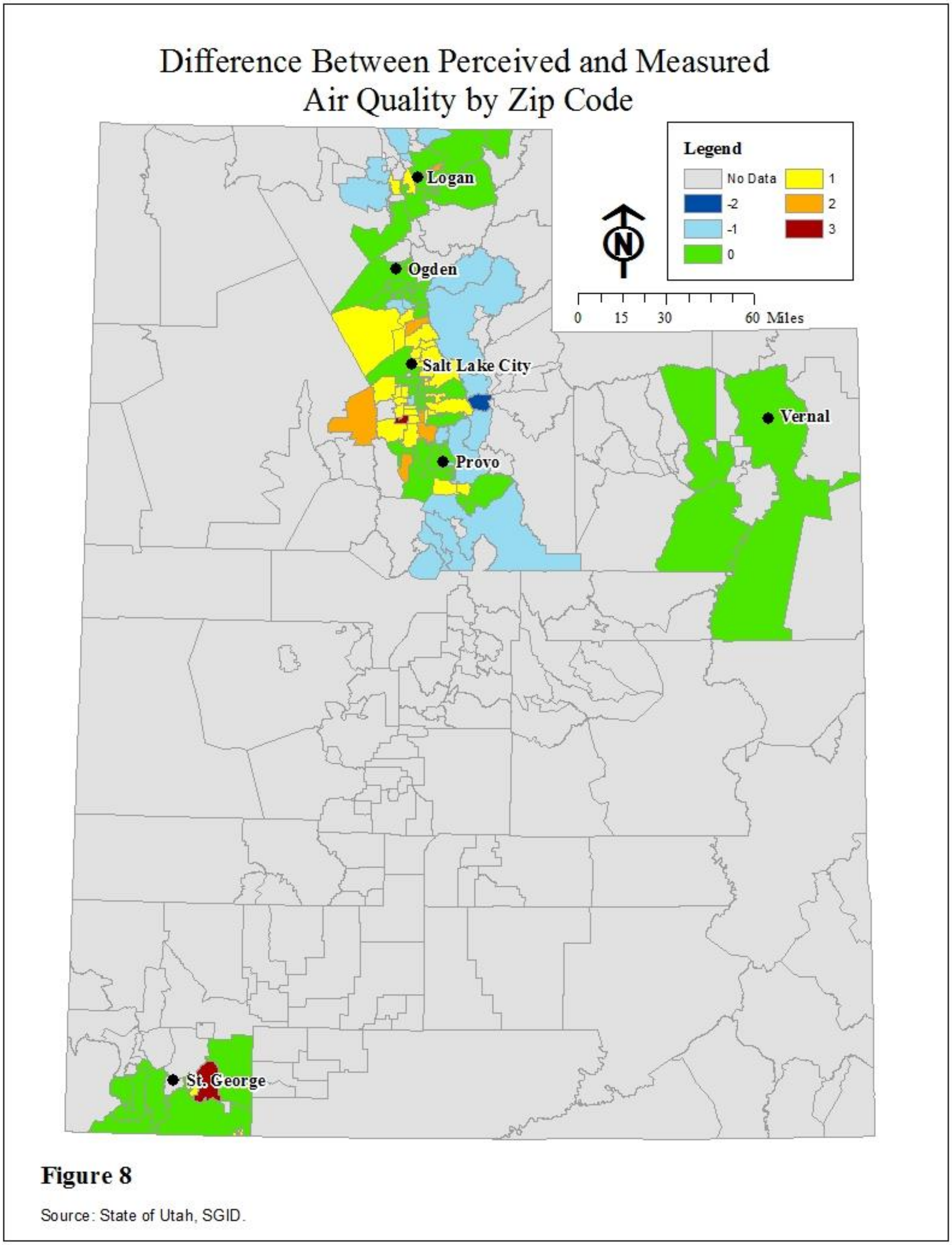

Figure 8 - Difference Between Perceived and Measured Air Quality by Zip Code

Multiple linear regression was used to determine the influence of factors, or predictor variables, associated with perceived of air quality (dependent variable) in Utah. Some variables may have similar relationships to the outcome and it is useful to investigate this while controlling for the other variables. Statistical analyses were performed using IBM SPSS. For this multiple linear regression, statistical significance was considered at the $p < 0.05$ level.

Perceived air quality was used as the dependent variable for the regression analysis. This is an ordinal variable using a progressive scale (Good to Hazardous). The accuracy score used in the spatial analysis was not chosen at the dependent variable because the scale varied from -2 to 3, with 0 being the most accurate (refer to Section 2.4, Comparing Air Quality Data). Interpreting the relationships between predictor variables and accuracy score on this scale would have proved problematic. Predictor variables, or factors that may influence perceived air quality for the regression analysis included: 1) measured air quality; 2) gender; 3) age; 4) education level; 5) political party affiliation; 6) religion; 7) county of residence; and 8) income. County was used instead of zip code as a category to simplify the analysis and to identify broad-scale geographic variation.

Most of the predictor variables used in the regression were categorical variables. Categorical variables are those that have two or more category choices. For example, the Qualtrics survey provided political party choices as Republican, Democrat, Independent, or Other. This variable is not on a continuous scale like age would be. The SPSS software does not consider that these variables are categorical, therefore dummy variables need to be created to ensure that each category is assigned a numeric value. For example, the sex variable has two categories: Male and Female. In the Qualtrics survey, respondents were coded as Male = 1, Female = 2. If we used these values, SPSS would assume that the sex Female has a value of 2 which does not make sense. For SPSS to process these sexes correctly, a dummy variable was created coding them to Male = 0, and Female =1. Every time a '1' value appears in the sex variable; the program now considers it Female. This process was repeated for the other categorical predictor variables that had more than one category (age, political party, education level, religion, county, and income). The original age data was collected by respondent's birth year. The age data was re-categorized into age bins. Older respondents could then be meaningfully compared to younger age groups.

There were many categories within some predictor variables. To simplify interpretation, some categories were consolidated, particularly where the number of respondents falling into a category was low (i.e., Hindu, Muslims, and Buddhists in the religious affiliation variable) or where categories were very similar (i.e., Independent and no preference political party). Table 3 shows how categories were consolidated for predictor categorical variables.

Consolidated Categories for Predictor Categorical Variables Used in Multiple Regression Analysis	
Independent Variable	*Consolidated Categories*
Gender	Male &Female
Political Party	Republican Democrat Independent/no preference Other
Education Level	< High school High school Some college no degree Bachelor's Masters/Doctorate
Religion	Protestant Catholic Baptist LDS/Mormon Other Christian Agnostic Atheist Other religion
County	Box Elder Cache Davis Duchesne Morgan Rich Summit Salt Lake Tooele Uintah Utah Wasatch Washington Weber
Age	18 to 24 25 to 34 35 to 44 45 to 54 55 to 64 65+
Income	<$20,000 $20,000 - $39,999 $40,000 - $59,999 $60,000 - $79,999 $80,000 - $99,999 $100,000 - $149,999 $150,000+ None specified

Table 3 - Consolidated Categories for Predictor Categorical Variables

Once the data had been consolidated and grouped appropriately, the multiple linear regression model was run. The program required that for predictor variables with more than two categories, a reference category be omitted from the inputs as a baseline to compare the other categories to. The reference categories for each predictor variable were chosen based on the largest number of responses from each variable as follows: 1) Age - 25 to 34 (302 responses); 2) Education – Some college no degree (330 responses); 3) Political party – Republican (478 responses); 4) Religion – LDS/Mormon (659 responses); 5) County – Salt Lake (520 responses); and 6) Income - $40,000-$59,999 (236 responses). When interpreting the output coefficients from the model, all coefficients are compared to these reference categories rather than the constant in the output table. Output data from the multiple linear regression is provided in Appendix B.

CHAPTER 3 RESULTS & DISCUSSION

3.1 Descriptive Survey Results

Figure 9 shows that 5.4% of the survey respondents perceived their local worst air quality day during the previous year to be good; 13.6% responded that air quality was moderate; 28.2% answered that air quality was unhealthy for sensitive groups; 18.4% of the respondents believed that the air quality was unhealthy; and 22.7% responded that air quality was very unhealthy. 11.6% also felt that the worst air quality day in their locale was hazardous.

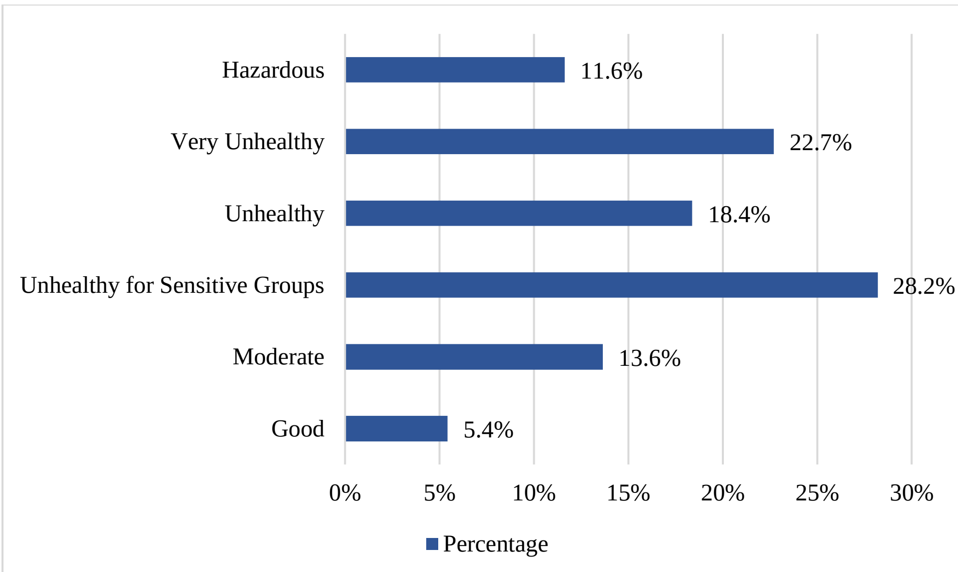

Figure 9 - AQI Responses for the Worst Day During the Past Year

The responses indicate that people were more likely to consider air quality unhealthy or worse than they were to consider it good or even moderate. Beyond personal experience, there may be additional factors that contribute to individual perceptions such as air quality reporting on the news, electronic billboards providing air quality index data to motorists, people living in dominantly urban areas where pollutants are higher, or perhaps families with school children are aware of restrictions for recess time when air quality reaches an unhealthy threshold.

Survey Demographics

As discussed in Section 1.4, Goals and Objectives, there have been previous studies that analyzed the links between demographics and air quality perception. Demographic data including gender, age, race, education, political party affiliation, religion, and income are described for survey participants.

More women responded to the survey than men. Females accounted for 61% of survey respondents and 39% were male.

Table 4 shows the age ranges for survey respondents within the 25-mile sensitivity analysis boundary. Respondents that did not provide birth year were removed from the statistics below.

Age Ranges for Survey Respondents		
Age Range	*Number of Survey Respondents*	*% of Total Respondents*
18-24	169	13.6
25-34	302	24.2
34-44	232	18.6
45-54	152	12.2
55-64	194	15.6
65+	197	15.8
TOTAL	**1,246**	**100%**

Table 4 - Age Ranges for Survey Respondents

The largest number (24.2%) of overall responses came from the 25 to 34-year-old age group. The lowest number of responses was from the 45 to 54-year-old age group. Response numbers were fairly well distributed between age groups. The possibility of under-sampling older age groups because of decreased internet access does not appear to have been a problem.

Respondents overwhelmingly identified themselves as white or Caucasian for the survey (87%). This is slightly more than the U.S. Census Bureau data (2016) which indicates that 78.8% of people residing in Utah are of white or Caucasian (not Hispanic) origin. Non-white respondents accounted for only 13% of the sample, and of that Hispanics accounted for the largest proportion at just 5% and Asians the second largest minority group at 3%. Minority percentages aligned with Census Bureau statistics (2016).

Education levels ranged from less than high school to masters or doctorate degrees among survey respondents. A very small number of respondents (1.5%) had a less than high school education. Those with a high school diploma represented 13.6% of respondents, and the largest group of respondents had some college with no degree (26.5%). Respondents with an associate degree accounted for 13.7% of respondents, 25.2% had a bachelor's degree, and 19.5% had a masters, doctorate, or professional degree.

Survey respondents identified with a variety of political parties. Registered voter survey respondents within the 25-mile sensitivity buffer were made up of 38% Republicans, 17% Democrats, 13% Independents, and 1% 'Other'. Thirty-one percent of respondents were not registered voters. Given that Utah has been a traditionally Republican state, these numbers could be considered surprising, particularly the high number of registered Independent voters.

A broad diversity of religious affiliations were represented as part of the survey. However, the dominant religion of respondents was LDS/Mormon (62.1%). Several other Christian denominations were identified including: Baptist (1.7%), Protestant (5.5%), Catholic (8.4%), Other Christian (8.3%), and Eastern Orthodox (0.7%). Agnostic (6%), and Atheist

(4.3%) respondents had smaller representation. Jewish (0.9%), Hindu (0.7%), Buddhist (0.7%) and other non-Christians (1.1%) had the smallest number of responses, and there were no self-identified Muslims who responded to the survey. These results are not surprising given that Utah has a predominantly LDS/Mormon population.

Annual income ranges varied from less than $20,000 to over $150,000. Table 5 shows the income categories with associated number of respondents and percentages.

Income Ranges for Survey Respondents		
Income Range	*# of Respondents*	*% of Respondents*
<$20,000	162	13.0
$20,000 - $39,999	226	18.1
$40,000 - $59,999	236	18.9
$60,000 - $79,999	210	16.9
$80,000 - $100,000	158	12.7
$100,000 - $149,000	171	13.7
$150,000+	75	6.0
None specified	8	0.7
TOTAL	**1,246**	**100**

Table 5 - Income Ranges for Survey Respondents

As Table 5 shows, the number of respondents in each income range were fairly similar with the exception of the most affluent respondents in the over $150,000 range representing just six percent of respondents. Fifty percent of all respondents earned less than $60,000 per year.

3.2 Spatial Results

A spatial analysis of air quality perceptions was important to the study because people's perceptions vary depending on the surrounding is which they live. Figure 6 showed that most zip code respondents along the Wasatch Front perceived the worst air quality day during the previous year as 'Unhealthy for Sensitive Groups' or 'Unhealthy'. Several zip codes within Salt Lake and Utah counties identified air quality as being 'Very Unhealthy'. Smaller clusters of zip codes near Logan, Bountiful and St. George also perceived air quality as 'Very Unhealthy'. Most of these zip codes were in urban valley areas where pollutant concentrations are usually higher, and pollution is highly visible.

Only one zip code (84009 – South Jordan Daybreak area) identified air quality as being hazardous. This is surprising because it is surrounded by zip codes that responded that air quality was unhealthy, two index categories less extreme. Daybreak is an area that has had substantial commercial and residential development recently. This may have resulted in a higher amount of construction traffic, or more particulate matter because of grading and construction activities. Alternatively, people may perceive greater pollution from the open pit Kennecott Copper Mine that is nearby.

More positive perceptions of air quality appeared to occur along the Wasatch Back (Heber, Midway and Park City) as well as in the Roosevelt, Vernal and St. George areas. Except for St. George, these zip codes generally have far less vehicle traffic and are at higher elevations which hinder the collection of pollutants close to the valley floors. St. George generally has better winter air quality because of a warmer climate and the topography does not lend itself to winter temperature inversions. None of the zip codes included in the analysis identified the worst air quality day as being ‘Good’.

Figure 7 visually represents the measured air quality data for the nearest monitoring station to each zip code. Like Figure 6, the majority of zip codes along the Wasatch Front exhibited measured air quality at the ‘Unhealthy for Sensitive Groups’ and ‘Unhealthy’ levels. Zip codes in the St. George area had ‘Moderate’ air quality on the worst air quality day, as did Vernal and Tooele. No zip codes had ‘Good’, ‘Very Unhealthy’, or ‘Hazardous’ measured air quality on the worst air quality day during the previous year.

As Figure 8 shows, from a geographic perspective there may be some relationship between where people live and the accuracy of their air quality perceptions. Respondents with the most accurate perceptions (an accuracy score of zero) lived in a wide variety of zip codes across the State. However, respondents who slightly underestimated air quality (an accuracy score of -1 or -2) appear to be located along the Wasatch Back (Coalville, Morgan, Park City, Heber, and Midway) and south Utah County (Spanish Fork, Payson, and Santaquin) as well as the Tremonton and Riverside areas in northern Utah. These respondents may reflect more positively on the air quality outlook because they live in more rural areas where pollution may not be as visible as in urban areas. Zip codes that slightly overestimated air quality (accuracy score = 1 or 2) were located along the Wasatch Front, particularly in Davis, Salt Lake and Utah counties. This is not a surprise given that these are the areas where inversion conditions are most likely to occur because of topography and higher vehicle emissions because of population concentration. One zip code in the St. George area also identified air quality as being worse than it was. This zip code is in the Zion National Park area. Zion National Park is in a narrow canyon that receives thousands of visitors in vehicles every year. Local residents may be more sensitive to air pollutants as a result of visibility and smell from vehicle emissions that would not normally occur in rural areas.

Table 6 shows that almost all zip codes had accuracy scores of -1, 0 and 1. Fifty zip codes had an accuracy score of zero indicating that respondents accurately perceived the air quality in their local area. Fewer zip codes (32) slightly overestimated the actual air quality in their area and twenty zip codes slightly underestimated the air quality in their local area. This indicates that on the whole, Utahns are fairly good at estimating what the air quality conditions actually are. There were a few zip code outliers that exhibited either extreme underestimation or extreme overestimation of air quality in their local area. Zip code 84060 (Park City) had an accuracy score of -2. Zip codes 84009 (South Jordan Daybreak area) and 84779 (Virgin/Zion National Park) showed extreme overestimation of their local air quality. As mentioned in Section 2.2, Spatial Analysis, Park City’s nearest monitoring station is Salt Lake City which may not have been an accurate representation of measured air quality data in the local area, hence the outlier.

Air Quality Accuracy Scores for Surveyed Zip Codes		
Accuracy Score	*Number of Zip Codes*	
-3	0	Underestimated Air Quality
-2	1	
-1	20	
0	50	Accurately Perceived Air Quality
1	32	Overestimated Air Quality
2	7	
3	2	

Table 6 – Air Quality Accuracy Scores for Surveyed Zip Codes

3.3 Quantitative Results

Multiple linear regression was used to predict perceived air quality from a set of predictor variables including measured air quality, gender, age, political party, religion, county of residence and income level. The null hypothesis for the multiple linear regression was that none of the predictor variables explain variance in perceived air quality. The regression output calculated an R square value of .247, meaning that 24.7% of the variance in total perceived air quality is explained by the model. Additionally, the p value for the overall model was calculated to be <0.05, therefore there is strong evidence to reject the null hypothesis. At least one of the predictor variables explained variance in perceived air quality.

Beta coefficients for the model demonstrated the effect size that each variable had on perceived air quality. P-values for the model indicated whether a variable was a statistically significant contributing factor for air quality perception. Beta coefficients and p-values for the independent variables are reported in this results discussion. Most of the independent variables were categorical “dummy” variables with reference categories selected based on the most common response in the data set. Measured air quality was included as a predictor variable to assess if the actual air quality had a bearing on people’s perception of air quality. The model calculated measured air quality as not being a significant predictor ($p=0.884$). This result aligns with the research of Dworkin and Pijawka (1982) and indicates that there may be a ‘halo’ effect occurring in certain areas in Utah (Brody et al., 2004). We could assume that those areas that underestimate air pollution such as Summit County, Uintah County, Wasatch County, southern Utah County and the very northern zip codes of Utah there is indeed a ‘halo’ effect occurring. This finding may also indicate that the air quality monitoring stations throughout Utah are not measuring the factors that people consider when thinking about air quality. Monitoring stations do not collect data on visibility, smell, or the fact that other meteorological events such as fog could be strongly linked to people’s air quality perception.

Gender was found to be a strong predictor variable ($p=0.001$) for air quality perception. Holding other variables constant, women perceived air quality to be worse than men (β coefficient = .235). This result is consistent with the research conducted by Tao and Lai (2003), as discussed in Section 1.4, Goals and Objectives.

None of the age categories were found to be statistically significant, or differ significantly from the most common age category, 25 to 34 years old. This result conflicts with prior research which found that older people tend to perceive air quality as poorer because they had memories of bad air pollution in the past (Howell et al., 2002). The results of this survey indicate that governments may not need to specifically target air quality communication based on age.

The education variable produced mixed results. The most common education level was "some college with no degree." Education levels that returned statistically significant differences from this level were less than high school (β coefficient = -.67, and $p=0.023$), and high school diploma (β coefficient = -.244, and $p=0.035$). People with less than a high school diploma underestimated air pollution to a greater degree than those with a high school diploma. These results indicate that governments and educators need to continue to educate those in high school about the causes, risks, and consequences associated with air pollution in order that awareness can improve.

Three household income categories returned statistically significant differences from the reference category, $40,000-$59,999: <$20,000, $20,000-$39,999, and $150,000+. Those earning less than $20,000 perceived air quality in their local area as being better than the reference category (β coefficient = -.309, and p-value = 0.015). This result is unexpected, based on the assumption that lower income groups would perceive air quality to be worse since they tend live in areas where air quality is poorer (Kim et. al (2012), Bickerstaff and Walker (2001)). Those earning $20,000-$39,999 (β coefficient = .238, and p-value = 0.035) and $150,000+ (β coefficient = .431, and p-value = 0.009) perceived air quality as slightly worse than those in the reference category. For the upper-income category, the result was consistent with Tiefenbacher and Hagelman's (1999) findings that suggested income is positively correlated with proximity to sources of air pollutants.

The most common reported political party affiliation was Republican The only political party affiliation that returned statistically significant differences from this reference category was among Democrats. Democrats identified air pollution as 0.427 ($p=0.00$) units (or AQI category) worse than Republicans. This was one of the larger differences amongst the demographic variables and is consistent with the fact that Democrats tend to have more pro-environmental views.

Religious affiliation was also included as a predictor variable, with the most common response (reference category) being "LDS/Mormon." Respondents who were affiliated with other Christian religions had somewhat different perceptions of air quality ($p=0.036$). Respondents in the "other Christian" category perceived air pollution as being slightly worse (β coefficient = 0.295) than the reference category (LDS/Mormon). No other religions returned a statistically significant difference. These results suggest that overall, religion is not a significant determinant of air quality perception.

As shown in the spatial analysis above, the regression analysis also revealed notable geographic differences in air quality perceptions even after controlling for demographics and measured air quality. Salt Lake County was the most common county of residence and the reference category. There were several counties of residence that returned statistically significant differences from Salt Lake County: Box Elder (p=0.028), Duchesne (p=0.044), Morgan (p=0.047), Summit (p=0.000), Uintah (p=0.000), Utah (p=0.001), Washington (p=0.000), and Weber (p=0.031). Table 7 shows the β coefficients for each of these significant counties.

	β Coefficients for Counties with Statistically Significant Differences from Salt Lake County							
	Box Elder	*Duchesne*	*Morgan*	*Summit*	*Uintah*	*Utah*	*Washington*	*Weber*
β Coefficient	-0.641	-1.101	-2.404	-1.947	-1.710	-0.35	-1.917	-0.273

Table 7 - β Coefficients for Counties with Statistically Significant Differences from Salt Lake County

A negative β coefficient indicates that respondents in the above counties perceived air quality as better than Salt Lake County. Duchesne, Morgan, Summit, Uintah and Washington returned very large coefficients indicating that they perceived air quality at least one unit (or AQI category), and in some cases close to two units higher than in Salt Lake County. Given the large number of statistically significant counties, we can conclude that geographic location is a significant component of people's air quality perception. However, it should be noted that several of these counties had very small numbers of respondents (<15). Duchesne had 5, Morgan had 1, Summit had 6, and Uintah had 12. Therefore, the model may not provide an accurate picture for these counties given the small number of responses. Additionally, it is worth noting again that there were drawbacks to using distance to monitoring stations in the sensitivity analysis. Residents of Morgan, Summit and Uintah Counties were all located in areas where regional topography separates them from their nearest air quality monitoring station. Therefore, perceived air quality compared to Salt Lake County does not necessarily provide meaningful results. In Utah County, respondents perceived air quality as being slightly better than in Salt Lake County. This is particularly surprising because measured results indicated that every monitoring station in Utah County (Lindon, Provo and Spanish Fork) had worse air pollution than any monitoring stations in Salt Lake County (see Table 2). This may be because residents of Utah County perceive Salt Lake County as being more urban with more industry and point source pollutants. It appears that in Utah County a 'halo effect' may be occurring, wherein residents are reluctant to attribute poor air quality to their local area (Brody et al.,2004). This information has important implications for state and local governments. Utah County residents need to have accurate and timely air quality information communicated more effectively in order that they can respond to the poor air quality they experience by changing their behavior.

CHAPTER 4 CONCLUSIONS

It is critical for many air quality stakeholders to come together and work cohesively if the air quality in Utah is to improve. Perhaps the most vital stakeholder is the Utah public. Collectively, an increase in pro-environmental behaviors by the public could make a significant difference in air quality conditions. As discussed in Section 3.2, Spatial Results, Utahns perceptions of air quality were fairly in-line with measured air quality conditions. Most respondents accurately perceived their local air quality conditions or were within one AQI category of error (see Table 6). This indicates that people could be encouraged to respond to the poor air quality they experience by changing their behavior. However, when a statistical analysis was conducted comparing measured air quality to perceived air quality, there was no statistical significant relationship found between measured air quality data and perceived air quality, suggesting that there are factors other than pollutants that people use to perceive their local air quality. The measured air quality at monitoring stations may not reflect people's actual experience since monitoring stations are dispersed at relatively few locations around the state, and air quality can vary substantially across small geographic areas. Policy makers need to keep in mind that people use more than just data to perceive air quality hazards such as visibility and smell. This is positive reinforcement for current clean air campaigns and information dissemination throughout the state. However, it also means that encouraging people to change behaviors needs to be approached from a holistic perspective, not just providing people facts and expecting a change.

The locations of the existing monitoring stations may not fairly assess how people on different socio-economic levels are perceiving air quality despite the Utah DEQ stating that locations are, "representative of local and regional pollution levels" (2017). For example, the Bountiful monitoring station is located approximately 1.5 miles northeast of an oil refinery. There are multiple lower-income homes and businesses in closer proximity to the refinery than there are surrounding the location of the existing monitoring station at Viewmont High School. A similar scenario may be occurring in other communities throughout the state that are experiencing negative air quality consequences compared to more affluent communities. Clean air is a highly desirable amenity and people that are more affluent are able move to areas with fewer air pollutants, whereas those in lower-income brackets may not have that opportunity because of financial barriers. It is essential that local policy makers educate and account for those in areas that have poor air quality to ensure that their health and quality of life can be good. Utah DAQ may need to think about relocating or adding monitoring stations to areas where pollutants are the greatest. This may be an unpopular political solution because it would increase pollutant readings and will have impacts on current and future SIP goals and objectives.

From a spatial perspective, there were a couple of zip codes that felt air quality was worse than it was, as compared to monitoring station data (Daybreak and Zion National Park areas). The statistical analysis also indicated that there are some socio-economic groups who identify air quality as more of a threat including females, Democrats, Other Christians and those earning more than $150,000 per year. On the other hand, there were areas that underestimated air pollution such as the Wasatch Back, southern Utah County and the Tremonton and Riverside. This was confirmed by the statistical analysis where Box Elder, Morgan, Summit, Uintah, Utah and Weber Counties all showed perceived air quality as being lower than Salt Lake County. Socioeconomic groups that perceived air quality as better than the reference categories included those with no high school diploma. Utah DAQ could try to tailor education towards those with less formal education (particularly in high schools) in those counties that underestimated air quality to help them understand the consequences of air pollution. Having one-on-one interactions and local meetings to discuss air quality problems could also help these communities gain a greater understanding about the issues in their local areas. Partnering with private and not-for-profit organizations would help Utah DAQ fill this educational gap which would hopefully incentivize pro-environmental behaviors.

This research brings to light the necessity of having an air quality monitoring network that is extensive and provides pollutant readings at finer geographic scales than is currently available. There were many respondents who lived within 25 miles of their nearest monitoring station. However, air quality differences occur over much smaller geographic distances than this. Additionally, this research showed that regional topography plays a role in how people perceive air quality compared to the measured readings at their nearest monitoring station. There may be financial barriers preventing the Utah DAQ from installing more monitoring stations throughout the state as funding is received through the Utah Legislature. Other political priorities may take precedent over air quality monitoring. Collaboration between Utah DAQ and private entities may help provide a clearer picture of how air quality varies at finer scales. There have been some efforts by private organizations and educational institutions such as PurpleAir (2018) and MesoWest through the University of Utah (2018) that are attempting to monitor air pollutants at finer geographic scales. Technology used by these organizations is advanced and can measure fine particulate matter at high spatial resolution. Monitors are now unobtrusive, small and can even be located on homes and transportation. Coordination between these groups is vital to increase our knowledge and provide the public with accurate, timely air quality information.

ACKNOWLEDGEMENTS

I am grateful to all of those with whom I have had the pleasure to work during this capstone project. The members of my MNR Committee have provided me with fantastic recommendations allowing me to contribute something of value to the natural resource field. I would especially like to thank Dr. Peter D. Howe, the Chair of my committee. He has been nothing but encouraging and supportive throughout the entire MNR Capstone process.

Nobody has been more important to me in the pursuit of this project than the members of my family. I would like to thank my parents and in-laws who have provided me with love and encouragement throughout my graduate studies. Most importantly, I wish to thank my loving and supportive husband, Nathan, and my four wonderful sons, Blake, Luke, Cole and Seth, who provide motivation and inspiration.

REFERENCES

Ainsaar, M., Hendrikson, R., Maasikmets, M., Orru, K. and Orru, H. 2015. Well-Being and Environmental Quality: Does Pollution Affect Life Satisfaction? Quality of Life Research, 25(3), 699-705.

Beard, J., Beck C., Graham R., Packham S., Traphagan, M., Giles, R., and Morgan, J. 2012. Winter Temperature Inversions and Emergency Department Visits for Asthma in Salt Lake County, Utah, 2003–2008. Environmental Health Perspectives, 120, 1385-1390.

Bird, B. 2017. The Air We Breathe Interview Transcript. Retrieved May 6, 2017 from http://www.kued.org/whatson/the-air-we-breathe/resources/interview-transcripts.

Bickerstaff, K. and Walker, G. 2001. Public understandings of air pollution: the 'localisation' of environmental risk. Global Environmental Change, 11(2), 133-145.

Brody, S., Highfield, B., and Peck, W. 2004. Examining Localized Patterns of Air Quality Perception in Texas: A Spatial and Statistical Analysis. Risk Analysis, 24(6), 1561-1574.

Centers for Disease Control and Prevention. 2018. Particle Pollution. Retrieved February 5, 2018 from https://www.cdc.gov/air/particulate_matter.html.

Chakraborty, J., Collins, T., Grineski, S. and Maldonado, A. 2017. Racial Differences in Perceptions of Air Pollution Health Risk: Does Environmental Exposure Matter? International Journal of Environmental Research and Public Health, 14(116).

Clean Air Act. 1970. (42 U.S.C Section 7401).

Dworkin, J., and Pijawka, K. 1982. Public Concern for Air Quality: Explaining Change in Toronto, Canada, 1967 - 1978. International Journal of Environmental Studies, 20(1), 17-26.

Elliott, S., Cole, D., Krueger, P., Voorberg, N., and Wakefield, S. 1999. The Power of Perception: Health Risk Attributed to Air Pollution in an Urban Industrial Neighbourhood. Risk Analysis. 1999, 19(4), 621-634.

Hausman, J., Ostro, B., and Wise, D. 1984. Air Pollution and Lost Work. NBER Working Paper No. 1263.

Heo, J., Adams, P., and Gao, O. 2016. Public Health Costs of Primary PM2.5 and Inorganic PM2.5 Precursor Emissions in the United States. Environmental Science & Technology, 50(11), 6061-6070.

Herbert, G. 2017. Governor's Position on Air Quality. Retrieved April 20, 2017 from https://www.utah.gov/governor/issues/airquality.html.

Howel, D., Moffatt, S., Prince, H., Bush, J., and Dunn, C. 2002. Urban Air Quality in North-East England: Exploring the Influences on Local Views and Perceptions. Risk Analysis, 22(1), 121-130.

Kim, M., Yi, O, and Kim, H. 2012. The role of differences in individual and community attributes in perceived air quality. Science of the Total Environment 425:20-26.

Lai, J.C. and Tao, J. 2003. Perception of environmental hazards in Hong Kong Chinese. Risk Analysis, 23(4):669-84.

Marquit, J. 2008. Threat Perception as a Determinant of ProEnvironmental Behaviors: Public Involvement in Air Pollution Abatement in Cache Valley, Utah. All Graduate Theses and Dissertations. Paper 188.

Mustafić, H. Jabre, P. and Caussin, C. 2012. Main Air Pollutants and Myocardial Infarction: A Systematic Review and Meta-analysis. The Journal of the American Medical Association, 307(7), 713-721.

Nickerson, R.S. 2003. Psychology and Environmental Change. Mahwah, NJ: Erlbaum.

Penrod, E. 2018, January 5. Utah's air pollution woes unlikely to clear up before 2024, state scientists say. The Salt Lake Tribune. Retrieved from www.sltrib.com.

Pope, A., Correia, A., Dockery, D., Wang, Y., Ezzati, M., and Dominici, F. 2013. Effect of Air Pollution Control on Life Expectancy in the United States: An Analysis of 545 U.S. Counties for the Period from 2000 to 2007. Epidemiology, 24(1), 23–31.

Pope, A., Ezzati, M., and Dockery, D. 2009. Fine-Particulate Air Pollution and Life Expectancy in the United States. The New England Journal of Medicine, 360, 376-386.

Purple Air. 2018. Purple Air: Air Quality Monitoring. Retrieved January 25, 2018 from https://www.purpleair.com/.

Salt Lake City. 2017. Winter Inversions: What Are They and What We Can All Do to Help. Retrieved May 3, 2017 from http://www.ci.slc.ut.us/winter-inversions-what-are-they-and-what-we-can-all-do-help.

Slovic, P. 1987. Perception of Risk. Science, 236(4799), 280-285.

Tiefenbacher, J. and Hagelman, R. 1999. Environmental equity in urban Texas: Race, income, and patterns of acute and chronic toxic air releases in Metropolitan counties. Urban Geography, 20(6), 516-533.

U.S. Census Bureau. 2016. Quick Facts Utah. Retrieved December 4, 2017 from https://www.census.gov/quickfacts/UT.

U.S. Congress. 1970. Clean Air Act, 42 U.S.C. §7401 et seq.

U.S. Environmental Protection Agency. 2011. The Benefits and Costs of the Clean Air Act from 1990 to 2020: Final Report, Table 5-6.

U. S. Environmental Protection Agency. 2014. Air Quality Index, A Guide to Air Quality and Your Health. Retrieved April 13, 2017 from https://www3.epa.gov/airnow/aqi_brochure_02_14.pdf.

U.S. Environmental Protection Agency. 2016a. News Release: EPA acts to reduce regional haze in Utah and improve visibility in National Parks. Retrieved April 21, 2017 from https://www.epa.gov/newsreleases/ epa-acts-reduce-regional-haze-utah-and-improve-visibility-national-parks.

U.S. Environmental Protection Agency. 2016b. Technical Assistance Document for the Reporting of Daily Air Quality - the Air Quality Index (AQI). Retrieved April 25, 2017 from https://www3.epa.gov/airnow/aqi-technical-assistance-document-may2016.pdf.

U.S Environmental Protection Agency. 2017a. Criteria Air Pollutants. Retrieved April 11, 2017 from https://www.epa.gov/criteria-air-pollutants.

U.S. Environmental Protection Agency. 2017b. Visibility and Regional Haze. Retrieved April 11, 2017 from https://www.epa.gov/visibility.

U. S. Environmental Protection Agency. 2017c. Summary of the Clean Air Act. Retrieved October 11, 2017 from https://www.epa.gov/laws-regulations/summary-clean-air-act.

U. S. Environmental Protection Agency. 2017d. Outdoor Air Quality Data: Download Daily Data. Retrieved November 14, 2017 from https://www.epa.gov/outdoor-air-quality-data/download-daily-data.

University of Utah. 2018. Retrieved January 25, 2018 from http://mesowest.utah.edu/.

Utah Department of Air Quality. 2017a. State Implementation Plan. Retrieved November 16, 2017 from https://deq.utah.gov/Laws_Rules/daq/sip/.

Utah Department of Air Quality. 2017b. $PM_{2.5}$ Moderate Area State Implementation Plans (SIP) (2009-2014). Retrieved November 16, 2017 from https://deq.utah.gov/Pollutants/P/pm/pm25/moderate-area-state-implementation-plans.htm.

Utah Department of Air Quality. 2017c. Serious Area $PM_{2.5}$ State Implementation Plan (SIP) Development. Retrieved November 17, 2017 from https://deq.utah.gov/Pollutants/P/pm/pm25/serious-area-state-implementation-plans/index.htm.

Utah Department of Air Quality. 2017d. Fact Sheet for Utah's Serious Area PM2.5 SIP Development. Retrieved November 17, 2017 from https://documents.deq.utah.gov/air-quality/pm25-serious-sip/DAQ-2017-002015.pdf.

Utah Department of Environmental Quality. 2016. Summer Ozone Season. Retrieved April 17, 2017 from https://deq.utah.gov/news/summer-ozone-season.

Utah Department of Environmental Quality. 2017. Utah Air Monitoring Program. Retrieved April 10, 2017 from http://www.airmonitoring.utah.gov/.

Utah Department of Environmental Quality. 2006. Utah PM10 Maintenance Provisions for Salt Lake County Section IX.A.10. Retrieved November 27, 2017 from https://deq.utah.gov/Laws_Rules/daq/sip/docs/2006/05May/secixa10slpmmaint.pdf.

Utah Department of Health. 2018. Ozone (O3). Retrieved February 5, 2018 from http://health.utah.gov/utahair/pollutants/O3/.

Utah Division of Air Quality. 2016. 2016 Annual Report. Retrieved May 6, 2017 from https://documents.deq.utah.gov/air-quality/annual-reports/DAQ-2017-001541.pdf.

Wang, S., Hipps, L., Chung, O., Gillies, R., and Martin, R. 2015. Long-Term Winter Inversion Properties in a Mountain Valley of the Western United States and Implications on Air Quality. Journal of Applied Meteorology and Climatology, 54(12), 2339-2352.

Zivin, G., Neidell, J, and Neidell, M. 2012. The Impact of Pollution on Worker Productivity. American Economic Review, 102(7), 3652-73.

APPENDIX A

Air Quality Summary for Each Zip Code

Air Quality Data for Zip Codes within a 25-Mile Buffer and with Survey Responses							
Zip Codes w/in 25-mile buffer and with survey responses	**Rounded Average Response**	**Average Response Category**	**Nearest Monitoring Station**	**Monitoring Station Code**	**Measured Worst AQI #**	**Measured AQI Category**	**Accuracy Score (response minus measured)**
84003	4	Unhealthy	Lindon	LI	4	Unhealthy	0
84004	3	Unhealthy for Sensitive Groups	Lindon	LI	4	Unhealthy	-1
84005	5	Very Unhealthy	Herriman	HE	3	Unhealthy for Sensitive Groups	2
84009	6	Hazardous	Herriman	HE	3	Unhealthy for Sensitive Groups	3
84010	4	Unhealthy	Bountiful	BO	3	Unhealthy for Sensitive Groups	1
84014	4	Unhealthy	Bountiful	BO	3	Unhealthy for Sensitive Groups	1
84015	3	Unhealthy for Sensitive Groups	Ogden	OG	4	Unhealthy	-1
84020	5	Very Unhealthy	Herriman	HE	3	Unhealthy for Sensitive Groups	2
84025	4	Unhealthy	Bountiful	BO	3	Unhealthy for	1

						Sensitive Groups	
84028	4	Unhealthy	Smithfield	SM	4	Unhealthy	0
84037	5	Very Unhealthy	Bountiful	BO	3	Unhealthy for Sensitive Groups	2
84040	4	Unhealthy	Ogden	OG	4	Unhealthy	0
84041	4	Unhealthy	Bountiful	BO	3	Unhealthy for Sensitive Groups	1
84042	3	Unhealthy for Sensitive Groups	Lindon	LI	4	Unhealthy	-1
84043	4	Unhealthy	Lindon	LI	4	Unhealthy	0
84044	4	Unhealthy	Magna	MA	3	Unhealthy for Sensitive Groups	1
84045	4	Unhealthy	Lindon	LI	4	Unhealthy	0
84047	4	Unhealthy	Salt Lake City	SL	4	Unhealthy	0
84049	3	Unhealthy for Sensitive Groups	Lindon	LI	4	Unhealthy	-1
84050	2	Moderate	Bountiful	BO	3	Unhealthy for Sensitive Groups	-1
84052	3	Unhealthy for Sensitive Groups	Roosevelt	RO	3	Unhealthy for Sensitive Groups	0
84054	5	Very Unhealthy	Rose Park	RP	4	Unhealthy	1

84056	3	Unhealthy for Sensitive Groups	Ogden	OG	4	Unhealthy	-1
84057	4	Unhealthy	Lindon	LI	4	Unhealthy	0
84058	4	Unhealthy	Lindon	LI	4	Unhealthy	0
84060	2	Moderate	Salt Lake City	SL	4	Unhealthy	-2
84062	4	Unhealthy	Lindon	LI	4	Unhealthy	0
84065	4	Unhealthy	Herriman	HE	3	Unhealthy for Sensitive Groups	1
84066	3	Unhealthy for Sensitive Groups	Roosevelt	RO	3	Unhealthy for Sensitive Groups	0
84067	4	Unhealthy	Ogden	OG	4	Unhealthy	0
84070	5	Very Unhealthy	Herriman	HE	3	Unhealthy for Sensitive Groups	2
84074	4	Unhealthy	Tooele	TO	2	Moderate	2
84075	4	Unhealthy	Bountiful	BO	3	Unhealthy for Sensitive Groups	1
84078	2	Moderate	Vernal	VE	2	Moderate	0
84081	4	Unhealthy	Herriman	HE	3	Unhealthy for Sensitive Groups	1
84084	4	Unhealthy	Magna	MA	3	Unhealthy for Sensitive Groups	1
84087	4	Unhealthy	Bountiful	BO	3	Unhealthy for	1

						Sensitive Groups	
84088	4	Unhealthy	Herriman	HE	3	Unhealthy for Sensitive Groups	1
84092	4	Unhealthy	Salt Lake City	SL	4	Unhealthy	0
84093	5	Very Unhealthy	Salt Lake City	SL	4	Unhealthy	1
84094	4	Unhealthy	Herriman	HE	3	Unhealthy for Sensitive Groups	1
84095	4	Unhealthy	Herriman	HE	3	Unhealthy for Sensitive Groups	1
84096	4	Unhealthy	Herriman	HE	3	Unhealthy for Sensitive Groups	1
84097	4	Unhealthy	Lindon	LI	4	Unhealthy	0
84098	3	Unhealthy for Sensitive Groups	Salt Lake City	SL	4	Unhealthy	-1
84101	4	Unhealthy	Salt Lake City	SL	4	Unhealthy	0
84102	5	Very Unhealthy	Salt Lake City	SL	4	Unhealthy	1
84103	5	Very Unhealthy	Salt Lake City	SL	4	Unhealthy	1
84104	4	Unhealthy	Rose Park	RP	4	Unhealthy	0
84105	5	Very Unhealthy	Salt Lake City	SL	4	Unhealthy	1
84106	4	Unhealthy	Salt Lake City	SL	4	Unhealthy	0

84107	4	Unhealthy	Salt Lake City	SL	4	Unhealthy	0
84108	5	Very Unhealthy	Salt Lake City	SL	4	Unhealthy	1
84109	4	Unhealthy	Salt Lake City	SL	4	Unhealthy	0
84111	4	Unhealthy	Salt Lake City	SL	4	Unhealthy	0
84112	5	Very Unhealthy	Salt Lake City	SL	4	Unhealthy	1
84115	4	Unhealthy	Salt Lake City	SL	4	Unhealthy	0
84116	4	Unhealthy	Rose Park	RP	4	Unhealthy	0
84117	4	Unhealthy	Salt Lake City	SL	4	Unhealthy	0
84118	4	Unhealthy	Magna	MA	3	Unhealthy for Sensitive Groups	1
84119	4	Unhealthy	Salt Lake City	SL	4	Unhealthy	0
84120	4	Unhealthy	Magna	MA	3	Unhealthy for Sensitive Groups	1
84121	5	Very Unhealthy	Salt Lake City	SL	4	Unhealthy	1
84123	4	Unhealthy	Salt Lake City	SL	4	Unhealthy	0
84124	5	Very Unhealthy	Salt Lake City	SL	4	Unhealthy	1
84128	4	Unhealthy	Magna	MA	3	Unhealthy for Sensitive Groups	1
84129	3	Unhealthy for	Salt Lake City	SL	4	Unhealthy	-1

		Sensitive Groups					
84302	4	Unhealthy	Brigham City	BC	4	Unhealthy	0
84305	3	Unhealthy for Sensitive Groups	Smithfield	SM	4	Unhealthy	-1
84309	5	Very Unhealthy	Smithfield	SM	4	Unhealthy	1
84312	3	Unhealthy for Sensitive Groups	Smithfield	SM	4	Unhealthy	-1
84315	4	Unhealthy	Ogden	OG	4	Unhealthy	0
84317	3	Unhealthy for Sensitive Groups	Ogden	OG	4	Unhealthy	-1
84318	6	Hazardous	Smithfield	SM	4	Unhealthy	2
84320	3	Unhealthy for Sensitive Groups	Smithfield	SM	4	Unhealthy	-1
84321	4	Unhealthy	Smithfield	SM	4	Unhealthy	0
84322	3	Unhealthy for Sensitive Groups	Smithfield	SM	4	Unhealthy	-1
84325	5	Very Unhealthy	Smithfield	SM	4	Unhealthy	1
84326	4	Unhealthy	Smithfield	SM	4	Unhealthy	0
84327	3	Unhealthy for Sensitive Groups	Smithfield	SM	4	Unhealthy	-1
84332	4	Unhealthy	Smithfield	SM	4	Unhealthy	0

84333	4	Unhealthy	Smithfield	SM	4	Unhealthy	0
84335	4	Unhealthy	Smithfield	SM	4	Unhealthy	0
84337	3	Unhealthy for Sensitive Groups	Brigham City	BC	4	Unhealthy	-1
84339	4	Unhealthy	Brigham City	BC	4	Unhealthy	0
84341	4	Unhealthy	Smithfield	SM	4	Unhealthy	0
84401	4	Unhealthy	Ogden	OG	4	Unhealthy	0
84403	4	Unhealthy	Ogden	OG	4	Unhealthy	0
84404	4	Unhealthy	Ogden	OG	4	Unhealthy	0
84405	4	Unhealthy	Ogden	OG	4	Unhealthy	0
84414	4	Unhealthy	Ogden	OG	4	Unhealthy	0
84601	4	Unhealthy	Provo	PR	3	Unhealthy for Sensitive Groups	1
84602	5	Very Unhealthy	Provo	PR	3	Unhealthy for Sensitive Groups	2
84604	3	Unhealthy for Sensitive Groups	Lindon	LI	4	Unhealthy	-1
84606	4	Unhealthy	Provo	PR	3	Unhealthy for Sensitive Groups	1
84645	3	Unhealthy for Sensitive Groups	Spanish Fork	SF	4	Unhealthy	-1
84651	3	Unhealthy for	Spanish Fork	SF	4	Unhealthy	-1

		Sensitive Groups					
84655	3	Unhealthy for Sensitive Groups	Spanish Fork	SF	4	Unhealthy	-1
84660	3	Unhealthy for Sensitive Groups	Spanish Fork	SF	4	Unhealthy	-1
84663	3	Unhealthy for Sensitive Groups	Provo	PR	3	Unhealthy for Sensitive Groups	0
84664	4	Unhealthy	Spanish Fork	SF	4	Unhealthy	0
84737	2	Moderate	St George	SG	2	Moderate	0
84738	2	Moderate	St George	SG	2	Moderate	0
84745	3	Unhealthy for Sensitive Groups	St George	SG	2	Moderate	1
84765	2	Moderate	St George	SG	2	Moderate	0
84767	2	Moderate	St George	SG	2	Moderate	0
84770	2	Moderate	St George	SG	2	Moderate	0
84774	2	Moderate	St George	SG	2	Moderate	0
84779	5	Very Unhealthy	St George	SG	2	Moderate	3
84780	2	Moderate	St George	SG	2	Moderate	0
84784	3	Unhealthy for Sensitive Groups	St George	SG	2	Moderate	1
84790	2	Moderate	St George	SG	2	Moderate	0

APPENDIX B

IBM SPSS Output Results

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT PerceivedAQ
  /METHOD=ENTER MeasuredAQ Gender1 Eighteen_twentyfour thirtyfive_fortyfour fo
rtyfive_fiftyfour
    fiftyfive_sixtyfour sixtyfiveplus LessthanHS HighSchool ASSOC BACHELORS MA
ST_DOCT Democrat
    Independent OtherParty Baptist Protestant Catholic OtherChristian Agnostic
 Atheist OtherReligions
    Nospecifiedreligion BoxElder Cache Davis Duchesne Morgan Rich Summit Tooel
e Uintah Utah Wasatch
    Washington Weber Under20000 twentythousandto39999 sixtythousandto79999 eig
htythousandto99999
    onehundredthousandto149999 onehundredfitythousandtplus noincomespecified
  /SCATTERPLOT=(*ZRESID ,*ZPRED)
  /RESIDUALS HISTOGRAM(ZRESID) NORMPROB(ZRESID).
```

Regression

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method

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Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	No income specified, Associates Dummy, Democrat Dummy, Wasatch Dummy, Rich Dummy, Morgan Dummy, Other Christian Dummy, Cache Dummy, Duchesne Dummy, Summit Dummy, Uintah Dummy, Tooele Dummy, Box Elder Dummy, Protestant Dummy, 80,000-99,999, Baptist Dummy, 45 to 54 Dummy, Washington Dummy, Other Party Dummy, Agnostic Dummy, Weber Dummy, Gender Dummy Variable, Other Religions Dummy, 150000+, 18 to 24 Dummy, Atheist Dummy, HS Dummy, Davis Dummy, < HS Dummy, Catholic Dummy, 60,000-79,999, 55 to 64 Dummy,	.	Enter

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a. Dependent Variable: Perceived AQ

b. All requested variables entered.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.497[a]	.247	.220	1.193

a. Predictors: (Constant), No income specified, Associates Dummy, Democrat Dummy, Wasatch Dummy, Rich Dummy, Morgan Dummy, Other Christian Dummy, Cache Dummy, Duchesne Dummy, Summit Dummy, Uintah Dummy, Tooele Dummy, Box Elder Dummy, Protestant Dummy, 80,000-99,999, Baptist Dummy, 45 to 54 Dummy, Washington Dummy, Other Party Dummy, Agnostic Dummy, Weber Dummy, Gender Dummy Variable, Other Religions Dummy, 150000+, 18 to 24 Dummy, Atheist Dummy, HS Dummy, Davis Dummy, < HS Dummy, Catholic Dummy, 60,000-79,999, 55 to 64 Dummy, 20,000-39999, Bachelors Dummy, No Specified Religion Dummy, 35 to 44 Dummy, Utah Dummy, 100,000-149,999, Ind_nopref Dummy, <$20,000, 65+ Dummy, Masters or Doctorate Dummy, Measured AQ

b. Dependent Variable: Perceived AQ

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	560.565	43	13.036	9.156	.000[b]
	Residual	1711.332	1202	1.424		
	Total	2271.897	1245			

a. Dependent Variable: Perceived AQ

b. Predictors: (Constant), No income specified, Associates Dummy, Democrat Dummy, Wasatch Dummy, Rich Dummy, Morgan Dummy, Other Christian Dummy, Cache Dummy, Duchesne Dummy, Summit Dummy, Uintah Dummy, Tooele Dummy, Box Elder Dummy, Protestant Dummy, 80,000-99,999, Baptist Dummy, 45 to 54 Dummy, Washington Dummy, Other Party Dummy, Agnostic Dummy, Weber Dummy, Gender Dummy Variable, Other Religions Dummy, 150000+, 18 to 24 Dummy, Atheist Dummy, HS Dummy, Davis Dummy, < HS Dummy, Catholic Dummy, 60,000-79,999, 55 to 64 Dummy, 20,000-39999, Bachelors Dummy, No Specified Religion Dummy, 35 to 44 Dummy, Utah Dummy, 100,000-149,999, Ind_nopref Dummy, <$20,000, 65+ Dummy, Masters or Doctorate Dummy, Measured AQ

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3.740	.337		11.087	.000
	Measured AQ	.013	.086	.006	.146	.884
	Gender Dummy Variable	.218	.073	.079	2.991	.003
	18 to 24 Dummy	-.187	.120	-.047	-1.565	.118
	35 to 44 Dummy	.125	.107	.036	1.167	.244
	45 to 54 Dummy	-.025	.123	-.006	-.203	.839
	55 to 64 Dummy	.038	.114	.010	.331	.740
	65+ Dummy	-.120	.118	-.032	-1.015	.310
	< HS Dummy	-.670	.294	-.061	-2.278	.023
	HS Dummy	-.244	.116	-.062	-2.116	.035
	Associates Dummy	.183	.114	.047	1.603	.109
	Bachelors Dummy	-.012	.100	-.004	-.124	.901
	Masters or Doctorate Dummy	.166	.116	.049	1.435	.151
	Democrat Dummy	.427	.111	.119	3.858	.000
	Ind_nopref Dummy	.030	.081	.011	.367	.714
	Other Party Dummy	.112	.310	.009	.360	.719
	Baptist Dummy	.005	.299	.000	.018	.986
	Protestant Dummy	.159	.174	.024	.914	.361
	Catholic Dummy	-.165	.145	-.031	-1.139	.255
	Other Christian Dummy	.295	.140	.056	2.100	.036
	Agnostic Dummy	.187	.161	.031	1.157	.248
	Atheist Dummy	.222	.195	.030	1.143	.253
	Other Religions Dummy	-.123	.209	-.016	-.589	.556
	No Specified Religion Dummy	.195	.108	.052	1.800	.072
	Box Elder Dummy	-.641	.291	-.057	-2.199	.028
	Cache Dummy	-.187	.160	-.032	-1.168	.243
	Davis Dummy	-.030	.113	-.007	-.269	.788
	Duchesne Dummy	-1.101	.547	-.052	-2.014	.044
	Morgan Dummy	-2.404	1.207	-.050	-1.992	.047
	Rich Dummy	.971	1.233	.020	.788	.431
	Summit Dummy	-1.947	.498	-.100	-3.908	.000
	Tooele Dummy	-.366	.303	-.035	-1.209	.227

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Coefficients[a]

Model	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
Uintah Dummy	-1.710	.380	-.124	-4.499	.000
Utah Dummy	-.350	.102	-.098	-3.418	.001
Wasatch Dummy	-1.033	1.206	-.022	-.856	.392
Washington Dummy	-1.917	.195	-.380	-9.835	.000
Weber Dummy	-.273	.127	-.060	-2.157	.031
<$20,000	-.309	.128	-.077	-2.425	.015
20,000-39999	.238	.113	.068	2.108	.035
60,000-79,999	.112	.117	.031	.961	.337
80,000-99,999	.092	.127	.023	.728	.467
100,000-149,999	.150	.127	.038	1.186	.236
150000+	.431	.164	.076	2.618	.009
No income specified	.380	.469	.021	.812	.417

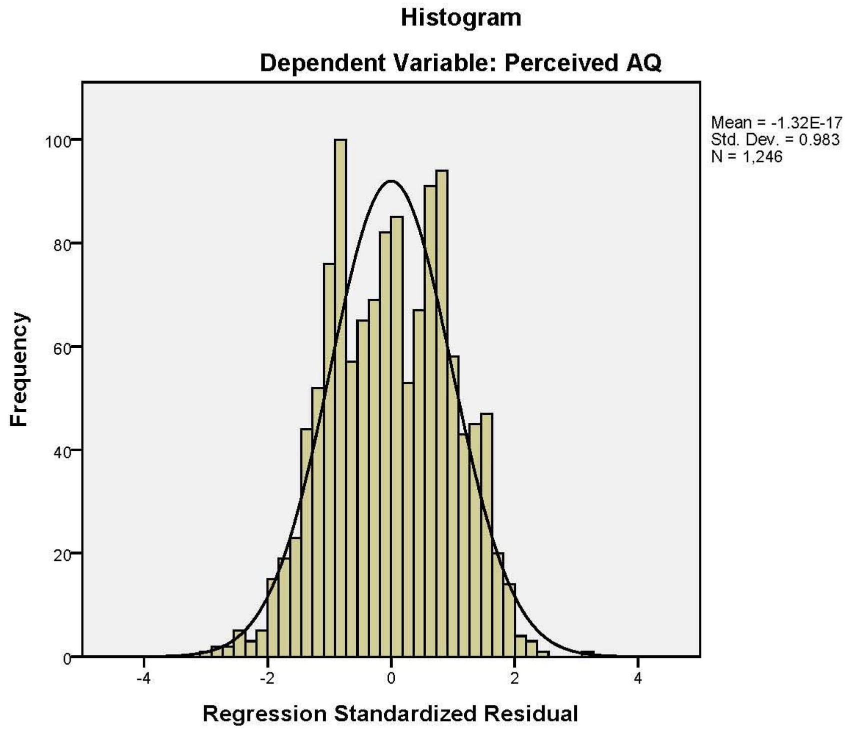
a. Dependent Variable: Perceived AQ

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	1.32	5.18	3.84	.671	1246
Residual	-3.608	3.870	.000	1.172	1246
Std. Predicted Value	-3.749	1.994	.000	1.000	1246
Std. Residual	-3.024	3.244	.000	.983	1246

a. Dependent Variable: Perceived AQ

Charts


Histogram
Dependent Variable: Perceived AQ
Mean = -1.32E-17
Std. Dev. = 0.983
N = 1,246
Frequency
100
80
60
40
20
0
-4
-2
0
2
4
Regression Standardized Residual

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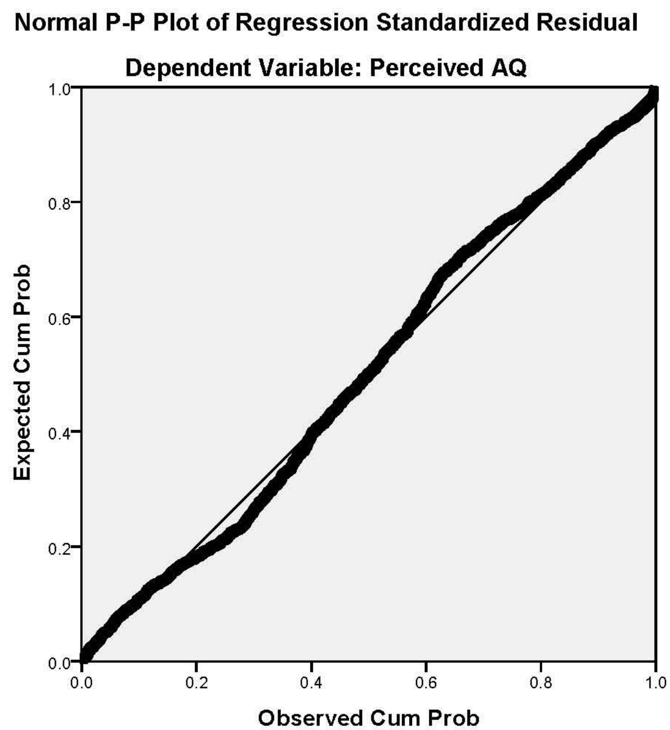
Normal P-P Plot of Regression Standardized Residual
Dependent Variable: Perceived AQ
Expected Cum Prob
Observed Cum Prob
0.0
0.2
0.4
0.6
0.8
1.0

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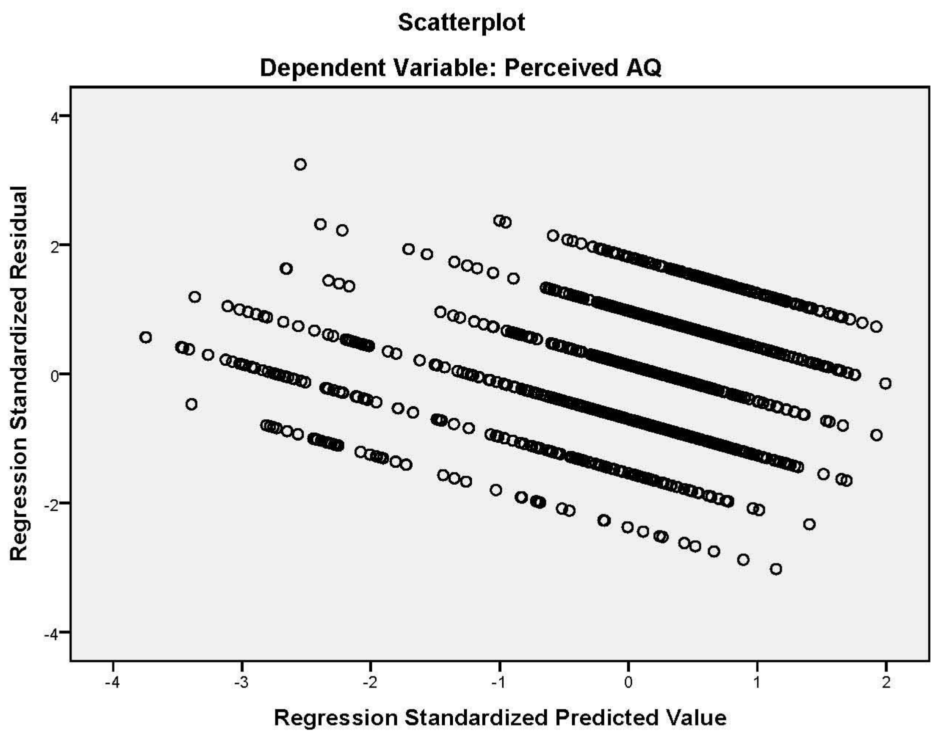
Scatterplot
Dependent Variable: Perceived AQ
Regression Standardized Residual
4
2
0
-2
-4
-4
-3
-2
-1
0
1
2
Regression Standardized Predicted Value